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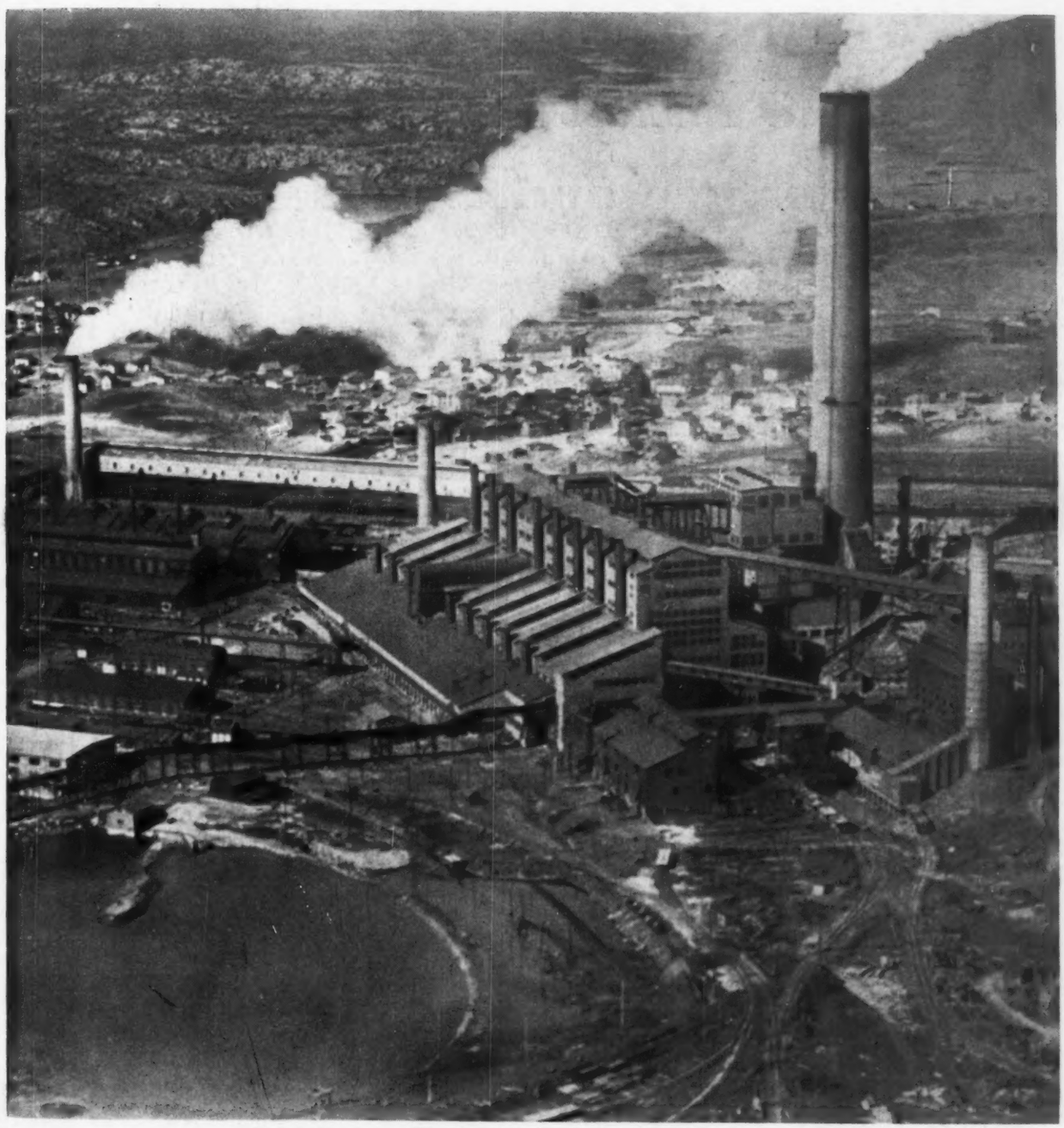

November 10, 1930, ISSUE

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ENGINEERING AND
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This issue was planned and produced under the direction of E. H. Robie, associate editor, formerly a member of the metallurgical staffs of the Canadian Copper and International Nickel companies.

The INCO Enterprise

Contents for November 10, 1930

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VOLUME 130 . . . NUMBER 9

Editorial 423
Foreword, R. C. Stanley 424
The Staff, J. L. Agnew 425
Historical Note, E. A. Collins 426
Research, A. J. Wadhams 429
Safety Work, E. A. Collins and G. S. Jarrett 431
Sudbury Ore, J. C. Nicholls 433
Mining Operations, Oliver Hall 435
Creighton Mine, R. D. Parker 437
Frood Shaft No. 3, A. F. Brock 443
Deep Mining at Frood, H. J. Mutz 445
Levack Mine, A. L. Sharpe 452
Frood Equipment, D. Butchart 454
Construction, J. H. Brace 455
Plant Design, L. M. Sheridan 460
Flotation, W. T. MacDonald 463
New Smelter, D. MacAskill and R. M. Coleman 473
Coniston Smelter, W. A. MacDonnell and J. F. Robertson 478
Chemical Production, J. M. Malcolm 479
Electric Power, W. E. Gillespie 480
Port Colborne Plant, R. L. Peek 482
Bayonne Foundry, E. S. Wheeler 488
Ontario Refinery, C. H. Aldrich and J. K. Bryan 489
Huntington Mill, H. S. Arnold and A. S. Shoffstall 493
Mond Operations, Mond Staff 495
News 498
Markets 501
Professional Directory 130
Searchlight Section 131
Advertising Index 136

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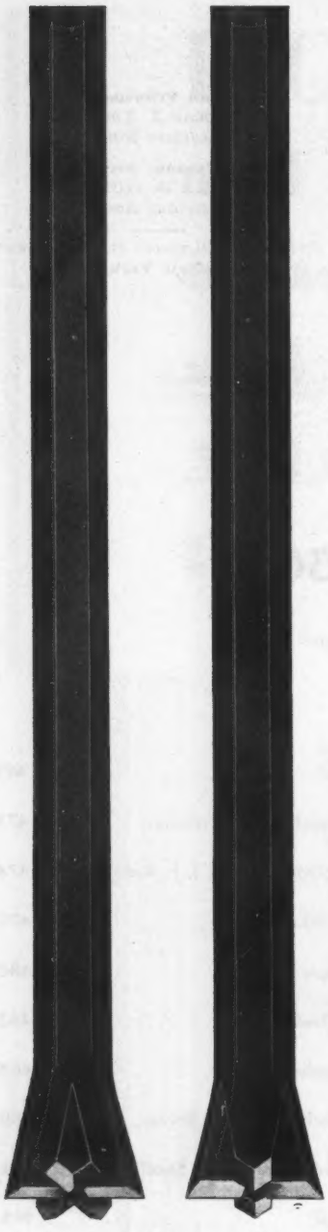

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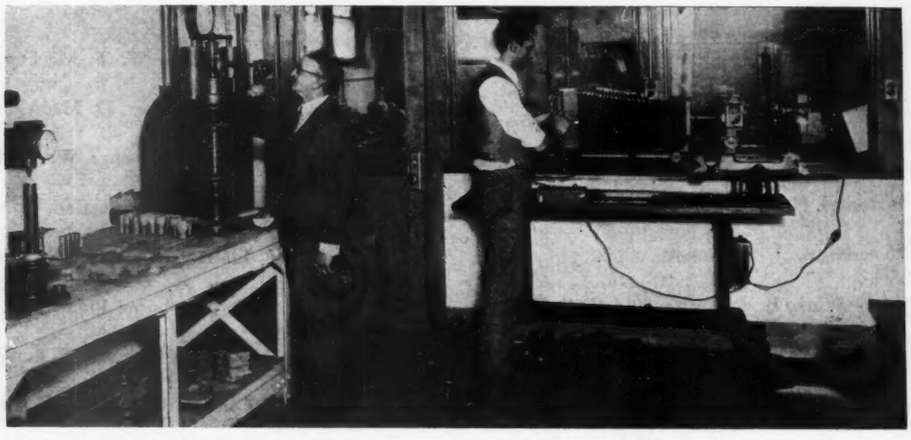

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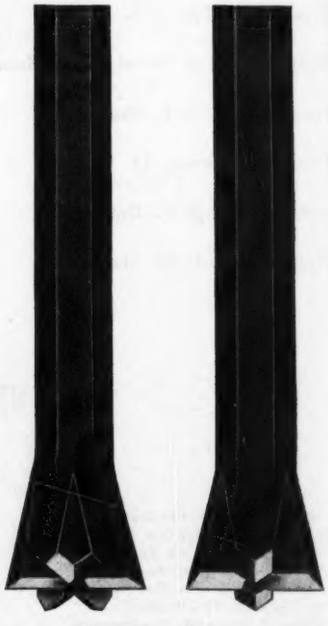

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ENGINEERING AND
MINING
JOURNAL

A. W. ALLEN, *Editor*

VOLUME 130, No. 9

ESTABLISHED 1866

New York, November 10, 1930

EDITORIAL

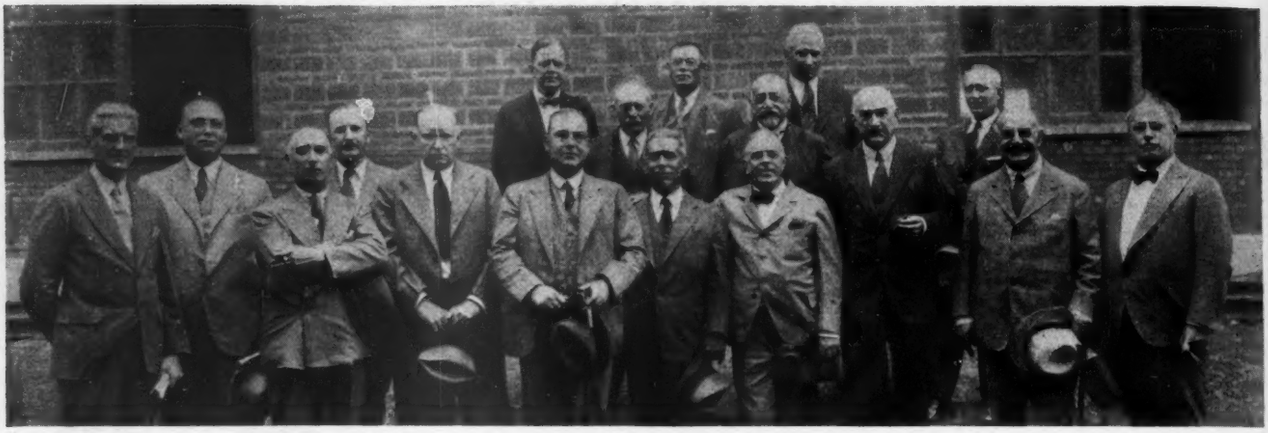
THE United States, the birthplace of large-scale mining operations on the surface and underground, is accustomed to spectacular achievement, the outcome, in major part, of a generosity in disclosing information on the methods adopted and technique developed in securing efficient technical results and profitable operation, concurrently with the maintenance of a high standard of living for employees of all grades. Among the other mining countries of the world, Canada leads in recognizing the value of research and the necessity for repeated modernization of ideas and practices; and this issue of *Engineering and Mining Journal* indicates that it is second to none in the possession of a spirit of helpful co-operation in the release of technical information, in recognizing that a debt is owed to those who have contributed to bring the industry as a whole to a high state of efficiency, and to the agencies that have effected an interchange of experiences and results that has stimulated progress and set new goals of attainment.

Few lines could be more imaginary than the one that divides the United States and Canada, particularly in regard to the attitude of members of the profession and industry of mining engineering in both countries. Canada in the past has been more than neighborly, giving to the United States many who have become honored leaders in its political and industrial life. Nothing exists that might temper an expression of appreciation and praise for the Dominion's swift attainment of industrial supremacy in the production of an important non-ferrous metal, and in the success achieved by the International Nickel Company of Canada in its diversified technical and industrial operations.

The United States is a major consumer of Canadian nickel, which is sufficient evidence of the sound position occupied by the metal in the industrial structure. With particular pride, therefore, *Engineering and Mining Journal* presents in this issue a comprehensive account of the operations, domestic and foreign, of Canada's greatest mining corporation—an account that reflects the high qualifications and energy of the directors of its destinies, and of the managerial ability and technical skill evidenced by those who have effected the consummation of elaborate and ambitious engineering plans.

Metal producers who are inclined to be pessimistic at the present state of affairs should find encouragement in a review of the recent history of International Nickel, beginning with the desperate straits in which the company found itself soon after the termination of the War, when its major markets were abruptly cut off. To meet this emergency, and to avoid what to many would have seemed an *impasse*, was brought a virility in initiative and performance that has few parallels in the history of commercial enterprise. The results are well known. Use of nickel is spreading rapidly, even in the United States, where none is produced. For this achievement, and for the example it presents, *Engineering and Mining Journal* extends its congratulations to those who, by faith and research and organization, and by persistence in exhausting every avenue of opportunity, have contributed to bring International Nickel into the ranks of the world's leading industrial institutions.

A. W. Allen



The Directors at Copper Cliff

Reading from left to right front row: 1. J. W. McConnell, Montreal; 2. James A. Richardson, Winnipeg; 3. The Rt. Hon. Lord Weir of Eastwood, P.C., Glasgow; 4. William J. Hutchinson, Englewood, N. J.; 5. James L. Ashley, New York; 6. John L. Agnew, Vice-President, Copper Cliff, Ontario; 7, Robert C. Stanley, President, New York; 8. Charles Hayden, Chairman of Board, New York; 9. Sir Harry McGowan, K.B.E., London; 10. The Rt. Hon. Lord Melchett, P.C., F.R.S., D.Sc., London; 11. John P. Bickell, Toronto. *Rear Row reading from left to right:* 12. Grant B. Shipley, Pittsburgh; 13. Britton Osler, K.C., Toronto; 14. Thomas Morrison, Pittsburgh; 15. Robert L. Mond, London; 16. D. Owen Evans, London; 17. Reg Halladay, Creskill, N. J. The following directors were not present: William E. Corey, New York; Wm. Nelson Cromwell, New York; William W. Mein, San Francisco; The Hon. Henry Mond, London; Seward Prosser, Englewood, N. J.; John Foster Dulles, New York; William T. Graham, Greenwich, Conn.; Andrew V. Stout, New York.

A FOREWORD AND AN APPRECIATION

By the President

IN selecting The International Nickel Company of Canada, Limited, for their annual comprehensive survey of the properties and operations of a metal company, the editors of the *Engineering and Mining Journal* doubtless consider that there is much in works layout and new equipment in the company's plants recently put into operation that will be of interest to the metal industry. I believe that interest in these new plants goes further than the professional study of new facilities for mining, smelting, and refining of copper-nickel ores.

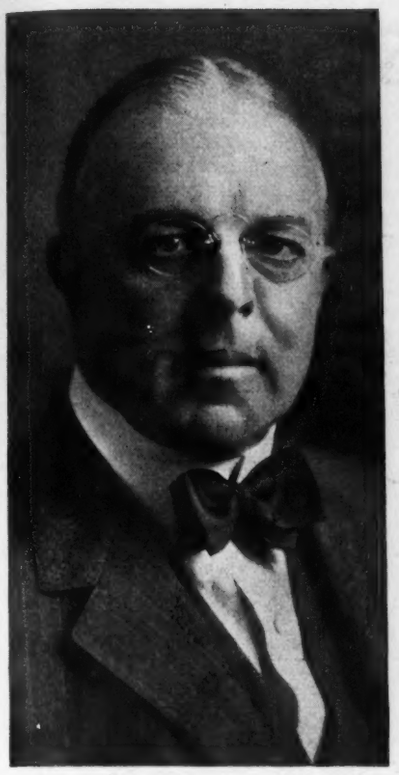
From the viewpoint of the industrialist, nickel has grown conspicuously in the comparatively brief post-war period. The fact that a war material has been well-nigh wholly converted into commercial usage is highly significant. Since the war period, during which The International Nickel Company, as a mining company, furnished the major portion of nickel required by manufacturers of war materials, the company has, through systematic research, development, and selling effort, become an industrial enterprise.

In addition to the researches conducted by my own company, which have originated new products for new fields of use, much important work on nickel alloys has been done by well-known industries both here and abroad. The recognized creative work of many important companies has not only supplemented the work on research and development of this company, but has on its own account contributed very substantially in extending markets for nickel.

The rapidity with which world-wide commercial applications of nickel grew necessitated provision for increased mining, smelting, and refining; therefore a construction program which centered about the now well-known Frood mine was formulated in 1924 and has involved large capital expenditures. The work is practically completed, and the plants, which are described in the following articles, constitute the most modern metallurgical unit now in operation and give assurance of an ample and reliable output of nickel to meet a rapidly increasing demand.

I believe that the engineering and metallurgical features described in this magazine are a great tribute to co-operation, engineering ability, and aggressiveness on the part of the company's operating organization.

PRESIDENT



Charles Hayden, Chairman

R. C. Stanley, President

J. L. Agnew, Vice-President

By the Vice-President

THE dominant position of The International Nickel Company of Canada, Limited, in the world trade in nickel, imposed on this company obligations as to continuity of supply and productive capacity which would possibly not be considered necessary by producers of other base metals, inasmuch as such metals may possibly be secured from many sources.

It being vital that consumers be fully protected as to their requirements of nickel at all times, a comprehensive program of enlargements and betterments was planned by the executives of this company. This was accomplished in separate steps, starting in 1924 and continuing to the present time, always with the above definite objective in view.

The effort has involved not only an expenditure of a large sum of money, but also a careful examination of the various problems from many angles, and in this regard I wish to place on record my keen appreciation of the assistance I have received from all those members of the staff who are heads of departments, and also from the different plant managers and their assistants, who by their loyalty, their devotion to duty, and by plain, hard, unremitting work have made possible the completion of the immense program of expansion undertaken particularly during the last four years.

Out of sheer necessity the work has been forced from the beginning, and there has been little time for leisure. In every department the work has steadily increased, and every department has responded to the demand.

I have no hesitation in stating that the accomplishments, such as they are, depicted in these pages by illustrations and detailed descriptions, reflect great credit on the combined efforts of a loyal and efficient staff.

J. L. Agnew

VICE-PRESIDENT

HOW THE INDUSTRY STARTED FIFTY YEARS AGO

—*E. A. Collins*
Assistant to the Vice-President

THE HISTORY of every great mining enterprise will prove, in most instances, the truth of the old copy-book maxim that "Tall oaks from little acorns grow." It will prove also, if carefully and truthfully compiled, that most of the great mining organizations of the present day owe their origin to one man or a very small group of men of remarkable vision and courage, and in this respect The International Nickel Company of Canada, Limited, is no exception. When one witnesses the magnitude of the present operations of the company, with huge plants in Canada, the United States, and Great Britain, and with trading ramifications reaching to every corner of the civilized world, the work of those pioneers of the '80s—S. J. Ritchie, H. P. McIntosh, Colonel Thompson, H. B. Payne, Francis Cornell, Stevenson Burke, James McArthur, and those associated with them in their struggle to inform a doubting world that nickel was really a useful metal—is presented in bold relief.

Opening the Copper Cliff mine, in 1886. Left to right are L. H. Ashmun, superintendent of the Canadian Copper Company; R. Frood, behind him; H. P. McIntosh, treasurer of the company; W. A. Hooker; and Archibald Blue. The beardless youth seen in the background must remain anonymous.

The first authentic discovery of nickel in the Sudbury district of Ontario was recorded by Alex. Murray, a member of the Dominion Geological Survey, who, in his reports to the Survey during the years 1853 to 1856, mentions the strong deviation of the compass noted by his assistant, Salter, near what is now the famous Creighton mine. Then the country was an undeveloped wilderness and settlers were few in number. Lumbering was the only industry until the Canadian Pacific Railway went through in 1883. The first discovery of ore in place was made in a rock-cut on the main line of the railway near what was later known as the Murray mine, another evidence that railway pathfinders often prove to be successful prospectors.

Without definite information on what they had found, the news of a great discovery spread throughout the camps and started a wave of prospecting. Men whose names have since become household words in the nickel industry joined in the rush. Among them were Thomas Frood, James Stobie, Rinaldo McConnell, F. C. Crean, J. H. Metcalf, Thomas Baycroft, W. B. McAllister, F. Y. Eyre, and William McVittie. Several of these hardy pioneers are still enjoying life and are ready at any time to discuss the old vs. the new methods of prospecting, hitting the trail with pack and canoe compared to the airplane journeys of modern days.

In 1884, 1885, and 1886, all the now known large deposits were located by the aforementioned group of prospectors, and in addition they traced the occurrence fairly completely around the rim or border of what has since become famous as the Sudbury basin. Their work in locating and developing the outcrops of nickel-copper ore in this area was done thoroughly and with the greatest attention to detail. They made important discoveries in the townships of Blezard, McKim, Snider, Creighton, and Denison, and later on in Garson and Levack. Then were the foundations laid for the immense developments described throughout this issue.

In Akron, Ohio, lived a man by the name of Samuel J. Ritchie. He was small of stature but big of spirit. He was a man of great vision, restless and untiring in his search for new business ventures, and whether he won or lost he kept up the search. Ritchie and his Ohio associates had developed a magnetic iron deposit near Coe Hill, in the County of Hastings, Ontario, and had connected this development with the Lake port of Trenton by over 100 miles of railroad. It cost a princely fortune to build, but when the mine was properly sampled they found the ore was a high-phosphorus, non-salable product, so there was no freight for the Central Ontario Railway.

Ritchie was in no way daunted. He had read of the "mountain of copper" which had been discovered near Sudbury in the Township of McKim. What could be better than to project the Central Ontario Railway to Sudbury and carry copper to tidewater instead of iron ore? He accordingly came to Sudbury in 1885, optioned or purchased the best prospects available, and formed the Canadian Copper Company to develop them. This company performed all the pioneer work in the development of the nickel industry and carried on until Dec. 31, 1918, when it lost its identity and was succeeded by The International Nickel Company of Canada, Limited.

In the spring of 1886 the Copper Cliff mine, in Lot 12, Concession 2, Township of McKim, was opened and later in the year a small force was put to work at the Stobie mine, in Lot 5, Concession 1, Blezard.

The year 1886 was destined to be a memorable one in the history of the company, owing to several important events that had a permanent and im-

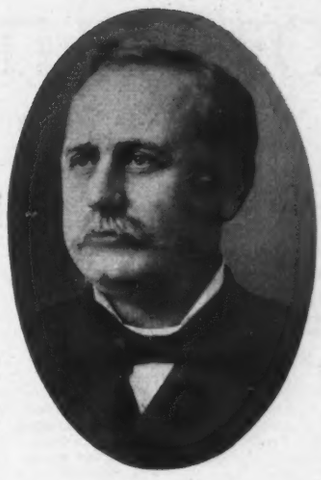
portant bearing upon its future. During that year the new discoveries and initial efforts were inspected by important Canadian statesmen and financiers in the persons of Sir Charles Tupper, Sir John and Lady MacDonald, William C. Van Horne, and George Stephens. Sir John MacDonald was Premier of Canada at the time, and Sir Charles Tupper his first lieutenant; Van Horne and Stephens were associated with Donald Smith, afterward Lord Strathcona, in the colossal task of building the Canadian Pacific Railway. Their visit meant much to the young company struggling to establish, on a firm basis, an industry in which at that time its biggest asset was a boundless faith in the unproved ore deposits and the ability to market its products. As a result of this visit, some years later Tupper accompanied Ritchie to England to acquaint the British government with the virtues of Canadian nickel. In October, 1886, it is also recorded in the Domesday Book that Ritchie purchased for the company the south half of Lot 7, Concession 6, Township of McKim, from Thomas Frood, P. C. Campbell, and Robert Tough, for $30,000. This was a large sum in those days to pay for a hillside with nothing but a highly colored gossan outcrop to indicate its value, and a few pine trees to add to its scenic beauty; still, it might be considered a fair bargain in the light of recent developments at the Frood mine, for it embraced this property, which was afterward named after the prospector who made the discovery. This Lot 7, Concession 6, McKim Township, the north half of which was acquired with the Mond properties in 1929, may prove to be the locus of the most valuable deposit of sulphide ore ever discovered in the world.

Throughout the year 1886 work progressed at the Copper Cliff mine. Nothing was known about the nickel content of the ore at first and hand-picked shipments of chalcopyrite were going forward to the Orford Copper Company at Constable Hook, N. J., a company headed by Col. Robert M. Thompson, one of the founders and first chairman of the board of the International Nickel Company.

Ritchie had carried on negotiations successfully with Colonel Thompson, and also with the Nichols Copper Company, which operated a copper smelter on Long Island. They both agreed to purchase the ore from Copper Cliff and both decided about the same time, after receiving several hundred cars of this material, that they didn't want any more. It contained something which played havoc with the usual copper-smelting practice. The Nichols company folded its tents and quietly stole out of the picture. To Thompson, failure meant financial ruin. He had already become acquainted with nickel in his venture many years previous with W. E. C. Eustis in developing the Eustis mine, in Quebec, and when his chemists reported the presence of a nickel content varying from 2 to 4 per cent in the Copper Cliff chalcopyrite he at once set to work to solve the metallurgical problems involved in the separation of the two metals. Volumes could be written of the struggles and failures and shattered hopes of the men at the head of both these companies engaged in the nickel industry during this period. At the Orford works, headed by the indomitable Colonel Thompson, the then known resources of the metallurgical world and all the processes of industrial chemistry were invoked to master the recalcitrant metal; finally their efforts were crowned with success by the discovery of the niter-cake process of separation still in use today.

At the Canadian property money was scarce and the development of mines to a producing stage was proving to be a slow and expensive business, especially when carried on in the hinterland of Ontario.

In 1887, owing to the cost of shipping green ore, the operators of the property decided to erect a smelter at Copper Cliff and reduce the ore to matte. The high sulphur content made roasting prior to blast-furnace smelting advisable, and the first roast bed was fired in January, 1887. This method of heap roasting was carried on continuously at the plant



Samuel J. Ritchie

until the construction of the new plant now in use, where mechanical roasters handle all the ore. What is probably the last example of open-heap roasting in America is thus ended.

An analysis of 600 tons shipped to Orford in July, 1887, ran as follows:

	Per Cent
Copper	10.17
Nickel	3.55
Silica	14.11
Sulphur	26.02
Iron	32.40

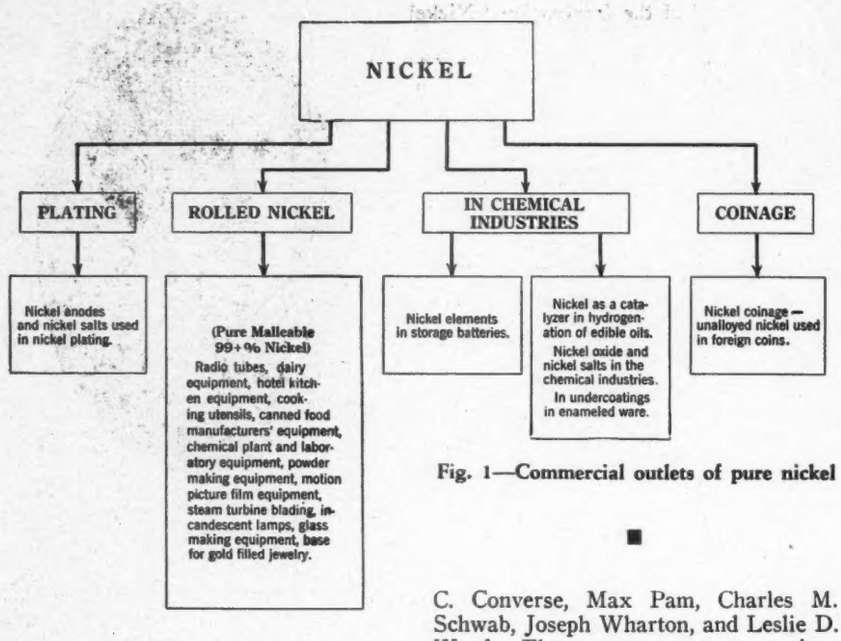
There didn't appear to be much profit in shipping this high-grade ore, for the records show that the manager was enthusiastic over the prospect of getting a smelter in operation and wrote his head office in Cleveland as follows: "It will be pleasant to cease working for the King of Prussia—as the Germans express it when working for nothing—and commence smelting ore on our own account."

The letter files of that period also show some interesting contrasts in the costs of labor and supplies when compared with present operations. In March, 1888, the manager reported that he would require between 4 and 5 tons of explosives for the rest of the year's operations and that his monthly labor payroll would amount to at least $4.500.

At this time Dr. Peters, of copper-smelting fame, was in charge of operations, and in July, 1888, James McArthur was brought from Butte to carry out Peters' ideas regarding the roasting and smelting of the ore. Peters left the employ shortly after, and for sixteen years, to 1904, McArthur was the guiding genius of the mining and smelting operations.

On Nov. 7, 1888, the report of ore in stock to feed the new 100-ton blast furnace showed the following: 18,948 tons of green ore from the Copper Cliff, Stobie, and Evans mines, with an average content of 4.71 per cent copper and 3.04 per cent nickel, and in addition to

The first house in Copper Cliff, 1886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Nickel elements in storage batteries.
Nickel as a catalyzer in hydrogenation of edible oils.
Nickel oxide and nickel salts in the chemical industries.
In undercoatings in enameled ware.
Nickel coinage — unalloyed nickel used in foreign coins.

Fig. 1—Commercial outlets of pure nickel

■

this amount, 7,880 tons of ore in roast heaps.

Peters reported that a furnace smelting 100 tons per day was enormous and unprecedented, and when asked if he could increase this smelting capacity to 300 tons per day, replied that such large figures were rather bewildering.

Concurrent with these activities at Copper Cliff in mining and smelting the ore, with their trials and tribulations, the Orford company was passing through similar stages in the refining and marketing of the new metal.

A paper on the properties of nickel in steel read in 1889 by James Riley, of Glasgow, before the Iron and Steel Institute of Great Britain may properly be credited with beginning the great nickel-steel industry. The history of nickel from then to the signing of the disarmament agreement by the Washington Conference in 1920 was closely united with the naval and military history of the different nations of the world, and most of the company's product was consumed in the manufacture of nickel steel for armaments.

In 1902, the International Nickel Company was formed. Included in the new corporation were the following diversified interests: The Canadian Copper Company, The Orford Copper Company, Wharton's American Nickel Works, The Anglo-American Iron Company, the Nickel Corporation of London, and the Société Minière Caledonienne, of New Caledonia. The officers and directors of the new company were as follows: President, Ambrose Monell; first vice-president, E. F. Wood; second vice-president, J. R. Delamar; secretary, S. H. P. Pell; treasurer, James L. Ashley; general counsel, Max Pam. Directors: Millard Hunsiker, S. H. P. Pell, A. W. Maconochie, A. H. Wiggin, Robert M. Thompson, Ambrose Monell, E. F. Wood, E. C. Converse, Max Pam, Charles M. Schwab, Joseph Wharton, and Leslie D. Ward. These were names to conjure with in the metal industry of America, and from the date of their assumption of control to the present, the company's history has been one of steady progress and expansion. In 1917, Ambrose Monell, president of the company, resigned to become an officer in the U. S. Army and was succeeded by W. A. Bostwick, who died in 1922, being succeeded by Robert C. Stanley. During the same year John L. Agnew, formerly manager of the mining and smelting operations of the company, became president of the Canadian subsidiary, known as The International Nickel Company of Canada, Limited, successor in 1918 to the former Canadian Copper Company.

In 1925, the properties and assets of the British America Nickel Corporation were purchased, and in 1929 a consolidation was effected whereby all the properties of the Mond Nickel Company, Limited, were acquired.

Thus from small and humble beginnings has grown and developed the giant corporation which controls today 90 per cent of the world's supply of nickel. Space is not available for recording what might be termed the romance of nickel, that period early in the present decade when the world's consumption dropped to a point on a par with that of 1900 and before. This record would set forth the efforts and accomplishments of R. C. Stanley and J. L. Agnew and their assistants, A. J. Wadhams, John F. Thompson, Paul D. Merica, and many others, who by scientific research and keen business acumen restored the market for nickel, so that in 1929, on a peace-time basis, it exceeded that of any year during the World War.

A letter from Dr. Peters to the head office, written on Nov. 13, 1888, states among other interesting items of news that "A young dude from the United States Geological Survey visited us today and states that no company can succeed who wastes the sulphuric acid as we do," and Dr. Peters adds his own comment that "All the fools are not dead yet." It would be interesting to know who this young dude was, and if he is alive today he might come to Copper Cliff again and inspect the large plants which not only utilize the converter gases for the manufacture of sulphuric acid, but complete the process by producing niter cake from the acid so made in conjunction with sodium sulphate found in immense quantities in the Province of Saskatchewan.

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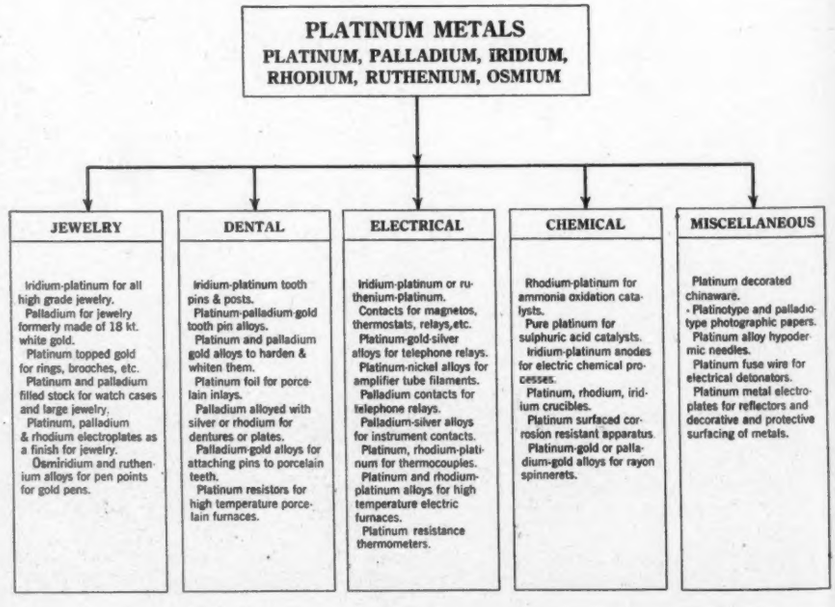
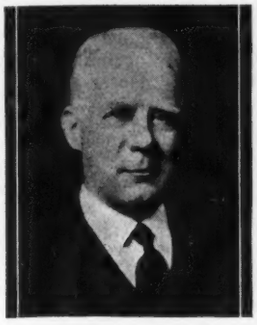
Fig. 2—Uses of nickel in ferrous alloys


PLATINUM METALS
PLATINUM, PALLADIUM, IRIDIUM, RHODIUM, RUTHENIUM, OSMIUM
JEWELRY
Iridium-platinum for all high grade jewelry.
Palladium for jewelry formerly made of 18 kt. white gold.
Platinum topped gold for rings, brooches, etc.
Platinum and palladium filled stock for watch cases and large jewelry.
Platinum, palladium & rhodium electroplates as a finish for jewelry.
Osmiridium and ruthenium alloys for pen points for gold pens.
DENTAL
Iridium-platinum tooth pins & posts.
Platinum-palladium-gold tooth pin alloys.
Platinum and palladium gold alloys to harden & whiten them.
Platinum foil for porcelain inlays.
Palladium alloyed with silver or rhodium for dentures or plates.
Palladium-gold alloys for attaching pins to porcelain teeth.
Platinum resistors for high temperature porcelain furnaces.
ELECTRICAL
Iridium-platinum or ruthenium-platinum.
Contacts for magnetos, thermostats, relays, etc.
Platinum-gold-silver alloys for telephone relays.
Platinum-nickel alloys for amplifier tube filaments.
Palladium contacts for telephone relays.
Palladium-silver alloys for instrument contacts.
Platinum, rhodium-platinum for thermocouples.
Platinum and rhodium-platinum alloys for high temperature electric furnaces.
Platinum resistance thermometers.
CHEMICAL
Rhodium-platinum for ammonia oxidation catalysts.
Pure platinum for sulphuric acid catalysts.
Iridium-platinum anodes for electric chemical processes.
Platinum, rhodium, iridium crucibles.
Platinum surfaced corrosion resistant apparatus.
Platinum-gold or palladium-gold alloys for rayon spinnerets.
MISCELLANEOUS
Platinum decorated chinaware.
Platinotype and palladiotype photographic papers.
Platinum alloy hypodermic needles.
Platinum fuse wire for electrical detonators.
Platinum metal electroplates for reflectors and decorative and protective surfacing of metals.

DEVELOPING NEW OUTLETS FOR INCO PRODUCTS

—*A. J. Wadhams*
Manager, Development and Research Department



RESEARCH is a term freely used today and with many different meanings; some form of research has become an accepted part of the activities of many industries. We have fundamental research, which may or may not have practical application; technical research, to improve processes of manufacture; and market research, to extend the uses of products. Of great importance during the last eight years has been the necessity for market research in the nickel industry, to find an outlet for a wartime metal in a world that decided to limit its armaments. Not only has a vast amount of work been done in the nickel industry, but the research of other industries has been of profit to International Nickel, as witness the development of stainless steel by Krupp at Essen, and of Permalloy by Western Electric.

International Nickel's department of development and research, covering the territory in the United States and Canada, is managed from the New York office. Main divisions are maintained in London, known as the Research and Development Department of the Mond Nickel Company, Limited; in Paris, known as the Centre d'Information du Nickel, with offices in Brussels and Milan; and in Frankfurt, known as Nickel-Informationsburo. The work comprises contact with industrial users and technical societies, and steady investigation to reveal new markets. Sometimes a change in present products is indicated, or the devising of an entirely new product. Co-operation must be extended to manufacturing plants working nickel alloys, and to their customers. Valuable information thus obtained must be made public through technical societies and publications in all parts of the world.

Nickel is marketed principally in four forms, as electrolytic, pellets, shot, and ingots; and the market outlet of nickel has three main divisions: pure nickel, ferrous alloys, and non-ferrous alloys. The uses of pure nickel are shown on p. 428. Nickel plating is used for widely diversified purposes and in fields subject to close technical control. Pure nickel coinage is constantly being more widely adopted and is now in use in 23 countries. A nickel-alkaline battery, with one element of pure nickel, has found favor because of its ability to withstand abuse and to have good recuperative powers after complete discharge. One use for nickel not mentioned on p. 428 has been found in the rayon industry, where very white caustic is desirable. This has led to the building of caustic soda evaporators and other handling equipment of pure nickel plates and tubing. Recently, a duplex metal of steel and pure nickel has been rolled in plates for building tank cars for caustic soda. Pure nickel is used for strainers at the bottom of deep oil wells, and for the plates and grids of radio tubes.

But more nickel is used in ferrous alloys than in any other way; some of the most important outlets in this field are shown on the next page. For such purposes, nickel is sold in the pure form to the steel mill or to the producer of iron or steel castings, who must meet the specifications of technical men in a host of different industries. The forging grades of nickel alloy steel, alloy cast steel, and the stainless steels have recently commanded growing interest, and the addition of nickel to cast iron is a development of recent years which has a wide application. A wide range of nickel-chromium alloys is now made which have superior endurance when subjected to intermittent heating and cooling.

The chart also indicates the more important uses of nickel in non-ferrous alloys. In many instances the choice of metals in this group is due to appearance rather than technical qualities, and the appeal must be made to the consuming public through general advertising. But non-ferrous nickel alloys have a wide appeal to the engineer as well, as witness the numerous technical uses of Monel metal.

The Sudbury nickel deposits have been the source of small quantities of platinum and palladium for many years, but with the present development of the Frood mine, and the improved refining operations, International Nickel will become a substantial producer of metals of the platinum group. Fig. 2 indicates the important commercial applications of these precious metals. The use of platinum for laboratory ware is well known, as is its applicability as a catalyst in sulphuric acid manufacture. Also, the production of nitric acid by the oxidation of ammonia in contact with red-hot platinum alloy gauze has become important with the synthetic production of low-cost ammonia. For electrical purposes, platinum has an established reputation for high-duty reliable contact points, and its use in oxide-coated radio tube filaments has made possible the manufacture of tubes with a useful life of 50,000 hours. The dental industry uses large quantities of platinum, as indicated in Fig. 2. Jewelry, however, consumes the largest proportion of platinum.

Palladium is far rarer than platinum and its properties are less generally known. It has the color and ductility of platinum but weighs only about half as much. It has the unique property of forming alloys with hydrogen, and, further, hydrogen readily passes through the slightly heated metal. The catalytic activity of palladium in promoting the hydrogenation of edible oils has been studied, but nickel is ordinarily used for that purpose. In certain reactions, the extreme activity of palladium may justify its use in preference to cheaper catalysts.

Palladium alloys, particularly those of palladium and gold, possess useful corrosion resistant properties, and palladium has been used extensively for contacts in telephone relays. Dental manufacturers find palladium-gold alloys useful for their strength and their light color, making them less conspicuous in the mouth; they seem likely to replace the old-style yellow and red golds for this purpose. Palladium can be readily electro-deposited for protecting surfaces from atmospheric tarnishing.

Iridium, rhodium, ruthenium, and osmium are also found associated with platinum, and in general act as hardeners when alloyed with that metal. But only platinum and palladium possess the ductility required for ready fabrication and exist in sufficient quantities for important commercial use. Active research to discover and develop new uses for

the platinum metals is under way in the laboratories at Bayonne, N. J., and Acton, England; also in the laboratories of the larger distributors.

The principal research laboratory of the company is at Bayonne, N. J., housed in a number of small buildings. A new laboratory building which will provide accommodations for all the activities will be completed this year. The equipment comprises furnaces of the usual type, hammer shop, heat-treatment furnaces, physical testing machines, corrosion testing material, electroplating equipment, microscopes, and a photographic room. Complete facilities are provided for the study of a wide range of alloys.

For many years the control laboratory of Henry Wiggin & Company, Limited, in Birmingham, England, has served the works where some forty different alloys are made and rolled, and has permitted carrying on research work. Recently, a new development research laboratory of The Mond Nickel Company, Limited, has been completed at Birmingham, where work similar to that at Bayonne will be carried on. The company has no research laboratory on the Continent, but has research arrangements at École Centrale, Paris, and Technische Hochschule, Aachen, for special studies of considerable importance. In addition, several laboratories are devoted to process research problems at the plants at Copper Cliff, Port Colborne, Huntington, Birmingham, and Clydach.

Ten years ago publications containing vital information on nickel were confined to one or two books containing chapters on nickel steels and a small number of well-known papers which had been read before one of the scientific societies. During the last few years a serious attempt has been made to publish and distribute sound information on the properties and performance of nickel and its alloys, not only that gained by our company but by others. The technical bulletins published by the company are designed for the engineer and contain both known and new information which will be useful to him in his work. Articles descriptive of special uses, not altogether technical, are published for more general distribution. Motion pictures showing the production, fabrication, and interesting applications of nickel alloys are also found to be of interest. The technical society journals are used for advertising. Reprints of these advertisements are sent to a long list of users or those who may become users. The advertisements usually feature specific applications and are based on definite facts and performance data that have been secured from various sources.

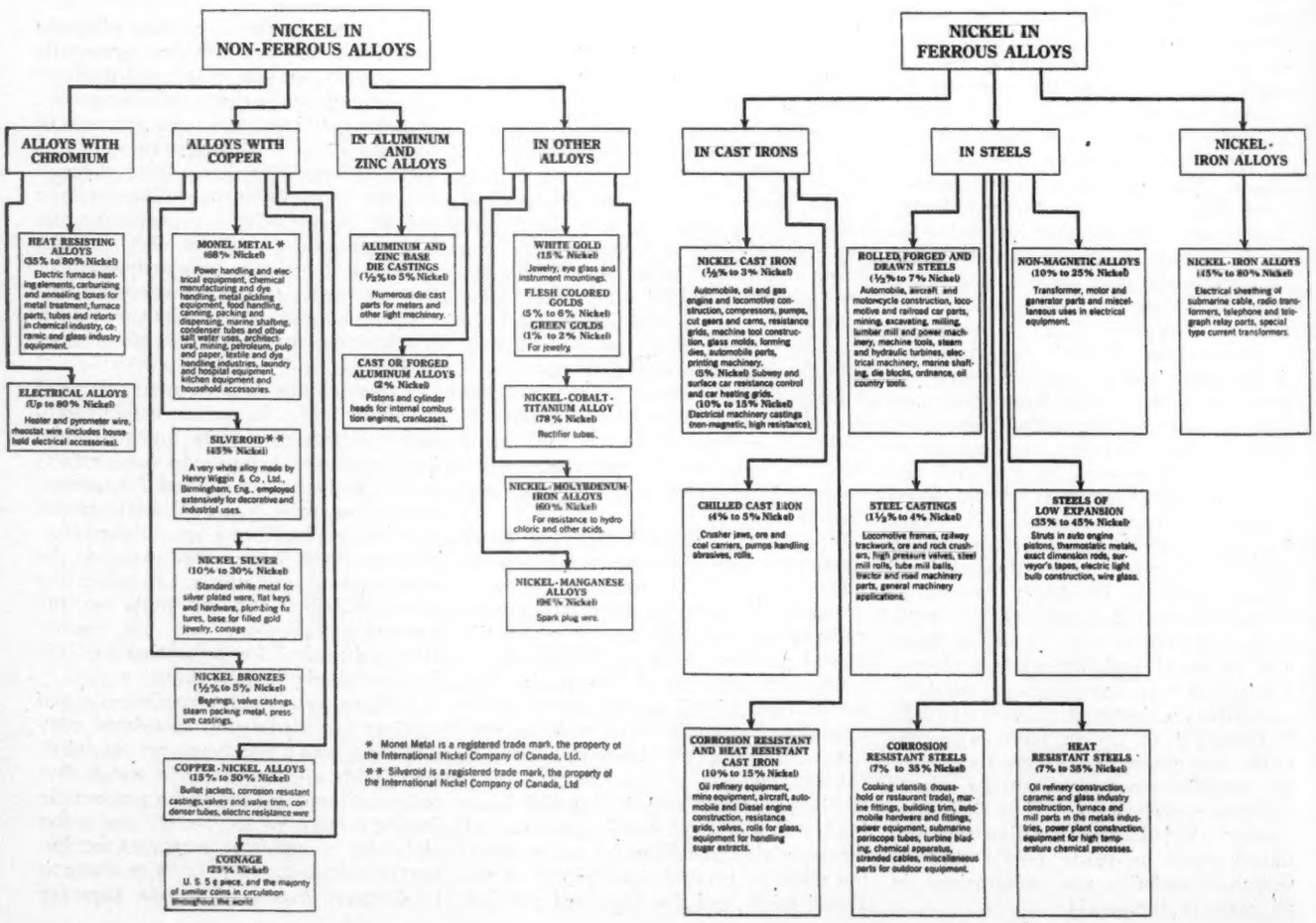
The magazine *Inco,* devoted largely to Monel metal, is issued in New York; also a paper called *Nickel Cast Iron News.* A monthly, known as *The Nickel Bulletin,* is issued in London, and for Continental Europe there is issued in Paris the *Revue du Nickel.*

Effective use is made of trade shows or expositions. The year's work would not be complete without the active round of conventions and their accompanying displays of products. These occasions afford the best opportunity to meet the large number of industrial operatives who use metals.

Nickel has found wide acceptance in industry because of its superior qualities when used in the pure form, and because of the widely varying properties of the alloys that can be made with other metals. The search for the best metal to fulfill a certain purpose usually involves development of the proper alloy, and the possibilities of nickel are limitless, as we are only in the early years of this art.

A bibliography of important articles on nickel appears on page 434.

Important Uses of Nickel in Various Alloys


NICKEL IN NON-FERROUS ALLOYS
ALLOYS WITH CHROMIUM
HEAT RESISTING ALLOYS (35% to 80% Nickel)
Electric furnace heating elements, carburizing and annealing boxes for metal treatment, furnace parts, tubes and retorts in chemical industry, ceramic and glass industry equipment.
ELECTRICAL ALLOYS (Up to 80% Nickel)
Heater and pyrometer wire, rheostat wire (includes household electrical accessories).
ALLOYS WITH COPPER
MONEL METAL * (68% Nickel)
Power handling and electrical equipment, chemical manufacturing and dye handling, metal packing equipment, food handling, canning, packing and dispensing, marine shafting, condenser tubes and other salt water uses, architectural, mining, petroleum, pulp and paper, textile and dye handling industries, laundry and hospital equipment, kitchen equipment and household accessories.
SILVEROID** (45% Nickel)
A very white alloy made by Henry Wiggin & Co., Ltd., Birmingham, Eng., employed extensively for decorative and industrial uses.
NICKEL SILVER (10% to 30% Nickel)
Standard white metal for silver plated ware, flat keys and hardware, plumbing fixtures, base for filled gold jewelry, coinage
NICKEL BRONZES (½% to 5% Nickel)
Bearings, valve castings, steam packing metal, pressure castings.
COPPER-NICKEL ALLOYS (15% to 30% Nickel)
Bullet jackets, corrosion resistant castings, valves and valve trim, condenser tubes, electric resistance wire
COINAGE (25% Nickel)
U. S. 5 ¢ piece, and the majority of similar coins in circulation throughout the world
IN ALUMINUM AND ZINC ALLOYS
ALUMINUM AND ZINC BASE DIE CASTINGS (½% to 5% Nickel)
Numerous die cast parts for meters and other light machinery.
CAST OR FORGED ALUMINUM ALLOYS (2% Nickel)
Pistons and cylinder heads for internal combustion engines, crankcases.
IN OTHER ALLOYS
WHITE GOLD (15% Nickel)
Jewelry, eye glass and instrument mountings.
FLESH COLORED GOLDS (5% to 6% Nickel)
GREEN GOLDS (1% to 2% Nickel)
For jewelry
NICKEL-COBALT-TITANIUM ALLOY (78% Nickel)
Rectifier tubes.
NICKEL-MOLYBDENUM-IRON ALLOYS (60% Nickel)
For resistance to hydrochloric and other acids.
NICKEL-MANGANESE ALLOYS (8% Nickel)
Spark plug wire.
* Monel Metal is a registered trade mark, the property of the International Nickel Company of Canada, Ltd.
** Silveroid is a registered trade mark, the property of the International Nickel Company of Canada, Ltd
NICKEL IN FERROUS ALLOYS
IN CAST IRONS
NICKEL CAST IRON (½% to 3% Nickel)
Automobile, oil and gas engine and locomotive construction, compressors, pumps, cut gears and cams, resistance grids, machine tool construction, glass molds, forming dies, automobile parts, printing machinery. (5% Nickel) Subway and surface car resistance control and car heating grids. (10% to 15% Nickel) Electrical machinery castings (non-magnetic, high resistance).
CHILLED CAST IRON (4% to 5% Nickel)
Crusher jaws, ore and coal carriers, pumps handling abrasives, rolls.
CORROSION RESISTANT AND HEAT RESISTANT CAST IRON (10% to 15% Nickel)
Oil refinery equipment, mine equipment, aircraft, automobile and Diesel engine construction, resistance grids, valves, rolls for glass, equipment for handling sugar extracts.
IN STEELS
ROLLED FORGED AND DRAWN STEELS (½% to 7% Nickel)
Automobile, aircraft and motorcycle construction, locomotive and railroad car parts, mining, excavating, milling, lumber mill and power machinery, machine tools, steam and hydraulic turbines, electrical machinery, marine shafting, die blocks, ordnance, oil country tools.
STEEL CASTINGS (1½% to 4% Nickel)
Locomotive frames, railway trackwork, ore and rock crushers, high pressure valves, steel mill rolls, tube mill balls, tractor and road machinery parts, general machinery applications.
CORROSION RESISTANT STEELS (7% to 35% Nickel)
Cooking utensils (household or restaurant trade), marine fittings, building trim, automobile hardware and fittings, power equipment, submarine periscope tubes, turbine blading, chemical apparatus, stranded cables, miscellaneous parts for outdoor equipment.
NON-MAGNETIC ALLOYS (10% to 25% Nickel)
Transformer, motor and generator parts and miscellaneous uses in electrical equipment.
STEELS OF LOW EXPANSION (35% to 45% Nickel)
Struts in auto engine pistons, thermostatic metals, exact dimension rods, surveyor's tapes, electric light bulb construction, wire glass.
HEAT RESISTANT STEELS (7% to 35% Nickel)
Oil refinery construction, ceramic and glass industry construction, furnace and mill parts in the metals industries, power plant construction, equipment for high temperature chemical processes.
NICKEL-IRON ALLOYS
NICKEL-IRON ALLOYS (45% to 80% Nickel)
Electrical sheathing of submarine cable, radio transformers, telephone and telegraph relay parts, special type current transformers.

SAFETY WORK AND INDUSTRIAL RELATIONS

—*E. A. Collins and George S. Jarrett*

Assistant to Vice-President, and General Safety Engineer, respectively

FEW organizations have maintained such cordial relations with employees of all classes as have been enjoyed by The International Nickel Company of Canada, Limited, successor since Dec. 31, 1918, to the Canadian Copper Company. It has, since its inception in 1886, been able to retain the confidence, good will, and loyalty of its employees to a remarkable degree. The following short outline will indicate some of the means taken by the company to insure this good will and efficiency.

Medical attendance for employees and their families has always been a major consideration of the company. In 1903, a hospital was erected at Copper Cliff, with accommodation for 26 patients. This building was destroyed by fire in 1912 and was immediately replaced by a larger fireproof stone, concrete, and hollow tile building, which is still in operation. It is equipped to accommodate 40 patients, but by furnishing extra wards this number could be increased to 60. All modern hospital devices and equipment have been provided, including operating room with Monel-metal tables, X-ray department, sun rooms, and a dispensary for out-patients.

The staff consists of a chief surgeon and twelve assistant surgeons, together with eight nurses, all experienced and highly qualified for the work.

The chief surgeon and five assistant surgeons reside in Copper Cliff and look after the medical requirements of employees and their families who live in that town. Two surgeons are located in Sudbury, where a dispensary is maintained for Frood employees and their families. There are also two at Coniston, and one each at Levack, Garson, and Creighton.

Industrial concerns established in urban centers have a decided advantage over Northern mining camps in the varied public entertainment available. This deficiency has been made up by the Nickel company in several ways. In 1915 a magnificent clubhouse was built at a cost of $85,000, including furnishings, taking the place of one built in 1901. This provides a large dance and assembly hall, reading room, billiard room, swimming tank and showers, bowling alleys, guest rooms, and dining room. It is operated by a committee of employees and has proved to be the social center of the town and district. For games such as football, baseball, and tennis, a large acreage has been set aside in the heart of the town of Copper Cliff and a covered curling rink is maintained for winter sports.

School facilities have been expanded as occasion demanded, the present fifteen-room building having been erected in 1922, at a cost of $125,000.

Shortly after the Dominion regulations governing insurance were modified to permit group insurance being written, the company initiated a plan of insurance for its employees. This is known as the Co-operative Life Insurance Plan, whereby insurance becomes effective six months after date of employment, provided an application has been made and applicant is still actively employed at the end of the six months' period. All regular employees are entitled to a policy amounting to $2,500 at a monthly cost of $1.75. Foremen and superintendents are entitled to increased amounts at equivalent rates.

Any employee may become a member of the Retirement System by filing with the board of administration a written application. Any member who has completed twenty years of credited service and who has attained the age of 65, if a man, or 60, if a woman, may, upon approval of the board, be retired, and shall receive a service pension payable monthly, equal to 1½ per cent of the member's average final compensation, multiplied by the number of his years of credited service, plus a pension equal to $6 multiplied by the number of his years of credited service. Any member who has completed ten years of credited service and becomes totally disabled before eligible for service retirement shall be entitled to a disability pension equal to 1¼ per cent of his average final compensation multiplied by the number of his years of credited service, plus a pension equal to $6 multiplied by the number of his years of credited service. The scheme also provides for a death benefit of $500.

Many different types of houses are rented to employees at nominal rates. A popular class of the cheaper style of construction, a four-room frame cottage, 20x20 ft., rents for $6 per month. A better type of five-room double tenement rents for $7 per month, and a still better class is a one-and-a-half story, frame and stucco construction, equipped with all conveniences, which rents for $14 to $15 per month. The next class is a seven-room, two-story cottage, of frame construction, with hardwood floors, lathed and plastered, stone basement, built at a cost of $4,700 each and renting for $19, with furnace. There is also a large number of better type, stucco construction, seven to nine rooms, renting for $25 to $35, chiefly for foremen and heads of departments.

International Nickel was the first mining company in the province to provide for a safety department in its organization, and to devote due consideration to the work of accident prevention. The duties of the general safety engineer include a periodical inspection of all mines and plants. All reports and recommendations are made in duplicate, one copy going to the superintendent in charge of the plant and the other direct to the management.

Typical houses at Copper Cliff

Reports giving detailed information regarding all accidents occurring at the various plants are forwarded to the office of the general safety engineer at Copper Cliff, and his office handles all correspondence with the Workmen's Compensation Board of Ontario. Once a month a report is compiled covering all lost-time accidents. A copy goes to the head of every department in the organization. The report includes a detailed account of all accidents, grouped by departments, as well as a summary, a classification of all accidents, and a statement showing the amount of compensation charged against each department. This affords the superintendent not only a review of his own accidents, but also enables him to know where and how accidents have occurred at the other plants. The summary is arranged to show the rate for each department in accidents and lost time per 1,000 shifts worked, compared with all other departments and with the total force.

Safety organizations at the plants comprise safety committees, consisting of the plant superintendent and his aids and the plant safety engineer. At Creighton and Frood mines this is augmented by a workmen's committee. Workmen elected by their fellow men act in a safety inspector's capacity for terms fixed by the mine superintendent. At Frood their term is six weeks, and the men spend one day every two weeks in going over the district assigned to them. They report at the end of the shift to the plant safety engineer, who acts as secretary to them. Copies of the recommendations as written out by him are forwarded to the divisional foreman and other officials. The workmen's committee at Creighton makes its inspection once every week and reports in a body to the mine superintendent at 2 p.m. the same day. The members of the committee hold office for four weeks only, but on the inspection day of the fourth week two men travel together, the committeeman-elect and the retiring one.

One essential in every safety movement is to maintain an aggressive interest among the shift bosses. Considerable success has been attained at the smelters through the use of shift bosses' accident record boards. One large board serves each department, and on it the number of accidents and days' lost time occurring on each shift are displayed in bold figures under the various shift bosses' names. These figures are entered by months as the year advances. At the end of the year the company pays a bonus to every shift with a clear board. The Copper Cliff smelter has so far this year established a very enviable record in view of the immense amount of construction work carried on in conjunction with the regular operations.

Once a month at Creighton mine a sheet is printed and distributed to all shift bosses, showing the rating of each in accidents per 1,000 shifts worked. At Frood, a similar sheet is distributed once every week. The Frood sheet, however, shows not only the rating for the past week but also a to-date rating. Several schemes of paying shift bosses a safety bonus have been tried at the various plants, but most of them have been allowed to drop, as it was not felt that they were having the desired effect. One is in operation at the Frood, however, which appears to possess certain advantages. By this arrangement each shift boss is entitled to $20 a month provided no man under his supervision suffers a lost-time accident. A lost-time accident occurring in the month incurs a penalty inversely proportional to the number of shifts credited to the boss.

Safety education among the men and the use of protective equipment are also stressed. Poster boards displaying National Safety Posters are used at all plants. At the Frood mine, where the payroll increase has been the greatest, each new man is given a short talk on safety as he waits for his medical examination. All bosses are instructed never to allow a new man to work alone until they are sure that the man understands the nature of the work. An effort is made to keep a new employee with an old miner for a period of a week. Strict discipline by shift bosses and foremen has also been found to assist in impressing safety rules on the men.

Recognizing the possibility of miners' being trapped in the event of an outbreak of fire underground, the company took steps years ago to insure that their operations were conducted as safely as possible. Creighton was then the only producer. All stations were cut off from the underground workings by fireproof doors, and fire-hose reels and hydrants were located inside the shaft doors on every level. Refuge stations were established on each of the main levels and have been kept in readiness for an emergency ever since. In addition to this, a rescue station was equipped, with ten sets of McCaa two-hour breathing apparatus and 24 Burrell all-service gas masks. Through an arrangement with W. G. Grove, of the Pittsburgh station of the U. S. Bureau of Mines, preliminary training of the rescue crews was given by him. For the last two years a class of from 30 to 40 men has been kept fully trained at all times. All regular members of the class are paid 25c. per day extra and must present themselves for two hours' training each month.

As rapidly as advancing development will allow, the Frood mine is being equipped with suitable fire-protection and refuge stations. Because of the 1929 amendment to the Ontario Mining Act that provided for the Workmen's Compensation Board to build, equip, and maintain a rescue station in the Sudbury and other mining districts, the company decided not to install rescue equipment of its own at Frood, but has assisted the Department of Mines in every possible way to expedite the construction of the station, which is now nearing completion on a site near the Frood mine, of easy access to the other properties of the district. All the rescue equipment is now on the property and arrangements are being made to organize teams and commence training at once, with the assistance of the instructor from Creighton.

THE SUDBURY ORE

—J. C. Nicholls

General Manager, Inco of Canada

ABOUT 90 per cent of the world's nickel is obtained from the Sudbury district, and has been for many years. Nickel ore is widely distributed over the earth's crust, but this district has become dominant owing to the concentration of the metal in large orebodies.

The Sudbury basin consists of an oyster-shaped area about 36 miles long and 16 miles wide, much of which is covered with glacial silt and gravel. The central part of the basin is flat for miles, but is relieved here and there by gentle undulations. On the edges it is entirely surrounded by rugged hills of conglomerate and norite - micropegmatite. Outside this rim are older rocks, mainly quartzite, graywacke, and arkose, which have been intruded by greenstones and granite of younger age.

Practically all of the rocks of the district are of Pre-Cambrian age. The oldest are those surrounding the basin and consist of a series of sediments such as quartzite, arkose, graywacke, slates, and conglomerates. These rocks, steeply tilted, folded, and partly metamorphosed by acid and basic intrusives, have been termed the Sudbury Series; they are equivalent to the Timiskaming Series of Cobalt and are therefore below the Lower Huronian. Associated with the Timiskaming Series are greenstones of doubtful age but evidently younger than the Timiskaming. Of later age and occupying the center of the basin is a series of sandstones, slates, tuffs, and conglomerates known as the Animikie Series.

The next younger in age is the Keweenawan Series, which is the most interesting from the standpoint of the nickel industry. A group of older gabbros, somewhat resembling the norite of the area, are of an age that has not been definitely ascertained. Next in age is the norite-micropegmatite, which occurs in large volume and entirely surrounds the basin. Still younger are the granites, and although their age is doubtful, they are probably younger than the norite-micropegmatite. After the intrusion and consolidation of the granite, the nickel-copper orebodies were probably formed somewhere near the contact of the norite and the older underlying rocks. Following the deposition of the orebodies came an intrusion of fine-grained diabase dikes. These were in turn cut by later olivine diabase dikes which intersect all rocks in the area.

Many brecciated areas occur in all of the rocks of the district. The fragments of rock composing the breccia may be cemented by some of the more finely crushed rock, but in some places, where the cementing material is the sulphides, these breccias constitute the commercial orebodies. Some rock inclusions are found in all the ores of the district, these varying in size from microscopic particles to blocks 20 ft. across. These breccias exhibit every gradation from those containing no sulphides at all to those which appear to contain nothing but clean sulphides.

All orebodies of the district have been found at or near the norite. Zones of shearing or brecciation near the contact of the norite and the underlying rocks have affected both the norite and the adjacent rocks, and orebodies may be found in the norite, in the adjacent rocks, or at the contact.

In all the mines that have been worked, the same general explanation of the formation of the orebodies seems to be applicable. Zones of shearing, or crushing, or brecciation have occurred near the norite contact, which was probably a line of weakness. Into this brecciated space was deposited at a later time the sulphides which form the commercial nickel-copper ore. There may have been successive periods of further brecciation, followed by other periods of sulphide deposition, these later ores having a different relative amount of the characteristic sulphide minerals. The position, size, and continuity of the brecciated spaces was controlled largely by the ability of the various rocks to resist crushing. Thus the tougher greenstone masses are possibly less broken, and the movements have expended themselves in the more brittle granite, gneiss, quartzite, or graywacke.

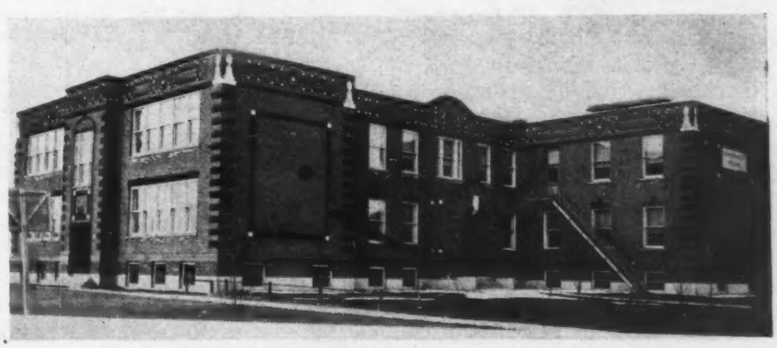
Much discussion has taken place regarding the source of the sulphide cementing materials and the method of their deposition. The major theories put forth are (1) magmatic segregation or igneous fluid injection, and (2) deposition from heated waters in brecciated spaces. Each of these has had ardent supporters from the early days of the district to the present.

Although ore has been found at separated places around the entire norite rim of the basin, the largest number of commercial deposits and the greatest number of mines which have been worked have been found along the south range in a line about 35 miles long.

The main sulphide mineral is pyrrhotite. With this is associated the copper mineral, chalcopyrite, and the nickel mineral, pentlandite. These form the bulk of the sulphides, though in some isolated places have been found some other copper and nickel minerals of no commercial importance. Generally, the nickel and the copper minerals are found in microscopic combination with the pyrrhotite, but in many parts of an orebody the pentlandite and the chalcopyrite may be found concentrated in large masses in a fairly pure condition.

Most of the orebodies occur on the higher portion of the rim of the basin, and their presence is indicated by gossan outcrops. It was these gossan showings which guided the early prospectors in

The Copper Cliff School



making mining locations. Also, the magnetic properties of pyrrhotite have led to a wide use of the magnetic needle in the search for ore. After the discovery of the gossan cappings, the orebodies were further explored by trenches and shallow winzes. The country at that time was covered with a heavy growth of pine, which made prospecting difficult.

Early in the history of the district the diamond drill was brought in to determine the size and character of the orebodies. The first holes were shallow and put down in an irregular manner, but as more knowledge of the deposits was gained, the drill was used more extensively, and now the extent of an orebody is known many years in advance of the extraction of the ore. Vertical holes up to a depth of 3,000 ft. have been put down. The system of laying out holes most in favor is that of a checkerboard plan with one axis parallel to the strike of the orebody. Diamond drilling is also used extensively underground to secure information regarding the downward extension of the ore, to sample more closely the ore about to be mined, and to get detailed information about the limits of the ore as an aid to development.

Some seem to be skeptical of results from diamond drilling, but when done systematically, and with a sufficient number of orebody intersections, this method has proved reliable. The percentage of core recovered in the orebody intersection is high. In some of the mines and portions of mines where diamond drilling has been done, the results have been checked against underground sampling, surveying, and actual ore extraction, and have been found to be dependable. With a systematic layout of a drilling scheme, and the proper interpretation of data, complete reliance can be placed on diamond-drilling results.

The Sudbury nickel-copper area

Copper Cliff's $85,000 clubhouse

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As It Seemed Then

From a reputable American mining journal, issue of Oct. 9, 1886:

"The 'mountain of copper,' near Sudbury, in Ontario, certified to by Sir George Stevens, loses its importance as we hear more about it. We understand that it is a large body of pyrrhotite, carrying stringers of copper pyrites through it. We have seen some of the ore, selected specimens of which carry from 8 to 13 per cent of copper. No silver or gold was found in it, though claims have been made that it contained these metals in large quantity. The copper is not abundant in the ore, and as the magnetic iron pyrites are worthless for the production of acid, the 'mountain' is likely again to bring forth very insignificant offspring after its labor."

MINES AND MINING OPERATIONS

Oliver Hall

General Superintendent of Mines

THE International Nickel Company of Canada, Limited, owns approximately 100,000 acres of mineral lands in the Sudbury district of northern Ontario; it has large ore reserves and excellent possibilities of opening up large additional reserves. Four mines, Frood, Creighton, Levack, and Garson, are in operation. Crean Hill, Murray, Stobie, and several other smaller mines could be opened if required.

The Frood Bonanza

The Frood is the largest orebody. Reserves in excess of 125,000,000 tons have been outlined, and the body is only partly explored. Following development near the surface, the orebody was thought to be of low grade, but diamond drilling and further development have indicated higher-grade ore at depth. The outcrop extends for more than a mile and has a width of over 600 ft. in places. The orebody occupies a long shear zone in graywacke, dips at about 65 deg., and has fairly regular walls. The breccia appearing at the surface changes with depth to a somewhat narrower, more compact body of disseminated ore, with areas of solid sulphide, and, deeper, to almost solid pyrrhotite, containing pentlandite (nickel sulphide) and chalcopyrite (copper sulphide), 40 to 200 ft. wide.

At present the Frood mine is producing about 4,000 tons a day, and it is being developed and equipped to produce 8,000 tons from the lower level higher-grade zone. Levels have been opened at 2,000, 2,200, 2,400, 2,600, and 2,800, and the mine is under development below 2,800. The amalgamation of the International and Mond companies in 1929 permitted the development of the mine as a unit and the use of both shafts.

Shaft-sinking, crosscutting, and preliminary opening up of the lower levels indicated somewhat difficult mining conditions. The graywacke is cut with a network of cross fissures, necessitating roofing the rock drifts with steel or timber. These conditions indicated that filling was advisable, and the horizontal cut-and-fill method has been used in most of the stopes. Stopes are 45 ft. wide and pillars 35 ft.

Pressure areas exist in the lower levels; these necessitate support of the stope roofs, as rips and minor rock blasts occur. In the cut-and-fill stopes we have worked out a system of lacing the back with timber supported by sets built up from the mill holes and cribs. In the more difficult areas we are square-setting, but we are using a modified square-set system, leaving the sets in along the two rows of mill holes in each of the 45-ft. stopes, and spanning between these and gob walls with long girts, which are removed as the filling is placed. This will cut down the serious fire hazard that square-sets involve.

Most mines have an individuality of their own, and several years of mining are necessary to disclose conditions and evolve the method or methods that meet the particular conditions.

The major operations will be carried on at the large, southerly six-compartment shaft, which will handle men and supplies and about 6,000 tons a day from the 3,000 pocket. The northerly shaft will be used to open up and hoist from the zone below the 2,800. Ventilation will be down a separate shaft used for that purpose only. Haulage and fill will be handled in Granby-type cars, storage locomotives being used in the orebody to gather trainloads, and trolley locomotives in the footwall haulage drifts and crosscuts to haul trains to ore pockets at the shafts. The tonnage required and depth have necessitated careful designing of plant and equipment.

The Famous Creighton

Creighton has been in operation for 30 years and has hoisted over eighteen million tons. It has substantial reserves in the 1,500- to 2,500-ft. zone, and diamond drilling has indicated large reserves below this zone. In 1929, 1,700,000 tons was hoisted. The main orebody dips at 45 deg. and follows a major fold in the trough of a horseshoe-shaped bay in the granite-norite contact. The main orebody is roughly lenticular, but is irregular, 500 to 1,000 ft. in length and 50 to 300 ft. wide. It occupies a shear zone near the norite contact. The north orebody lies to the north of the main orebody. It was discovered by underground exploration and is minable below the eighteenth level. It is in a minor fold of the norite bay. It dips at from 35 to 60 deg. and is from 300 to 700 ft. long and 20 to 100 ft. wide. It occupies a shear zone near the norite contact.

Broadly speaking, Creighton has had three mining stages—the mining of the upper 300 ft. of the main body by open cut, the mining of the main body below this by shrinkage, and the mining of the north orebody by shrinkage, and latterly cut-and-fill and square-setting in some of the lower-level stopes where the backs are heavy.

Creighton was mined to 300 ft. by open-cast quarrying, a large tonnage being secured at a very low cost by this method. When open casting became impracticable, new shafts were sunk, a new plant was built, new hoists were installed, and the mine was placed on a large-production basis. Main levels were opened at 120-ft. vertical intervals.

Haulage drifts were driven in the footwall roughly parallel to the orebody. Crosscuts across the ore were driven at 75-ft. centers on the center line of the pillars. Fifteen-foot rib pillars were left and 60-ft. stopes between pillars were mined by shrinkage. The ore was drawn through boxholes driven from the footwall drifts and crosscuts. Sublevel drifts were driven between main levels to clear the footwall during mining and during the final drawing. Mining by this method was at first carried on under an open top. The hanging wall eventually caved in large blocks, forming a fairly natural mat, and successive caves filled the former open top. From this stage on, shrinkage was carried on beneath the cave, and it became essential to work out definite systems for the extraction of the level floors and pillars and for the even pulling of the ore below the cave.

The floors were posted with round posts when the stopes reached within about 25 ft. of a finished level. They were then broken through at the hanging, and mined back to the footwall. The pillars before the caved period were shot along the foot and hanging. In the deeper levels the pillars were increased to 25 ft. A system of drifts and raises were driven through the pillars to drill them out, and they were shot in blocks. Latterly, the pillars were drilled out from vertical raises, and the pillars, and in some cases the

floors, were shot with electric blasts.

The upper part of the north orebody was mined by shrinkage, scrapers being used when the footwall was under 45 deg. In the deeper levels the backs are weak and a part of the orebody has been mined by cut-and-fill or square-sets.

An interesting feature of the Creighton operations now under way is the supplying of crushed rock to Frood for fill. Two to three thousand tons a day will eventually be required. The upper Creighton workings are full of material caved from the hanging wall containing areas of ore. They also contain a large tonnage of rock and low-grade ore sorted out of the ore shipped. The fill in the upper workings will now be hoisted, recrushed, and passed over screens and magnetic pulleys. Fines and magnetic ore will go to the new concentrator at Copper Cliff and the crushed rock to Frood mine. Fill will also be required in the lower Creighton stopes, and Creighton mine will procure its own fill from the same source.

Creighton is still a fine mine with a long future. The lower workings indicate somewhat heavier ground, and mining methods must be devised, as in the past, suitable to conditions as they are met.

The Levack Mine

Levack has been in operation since 1914. It has important reserves opened up above the seventh, or 590-ft., level, and diamond drilling has indicated large reserves below this level. It is opening up the ninth and eleventh levels at 120-ft. intervals below the seventh level and has plant and equipment capable of handling 3,000 tons a day.

Levack's orebody is at the westerly end of the nickel field, and Levack is the only operating mine on the North Range. The orebody had only a small outcrop, an area about 50x50 ft. at the base of a ridge of gneiss, but differential magnetic surveys followed by diamond drilling in 1913 indicated a large orebody. The body is quite small above the 250-ft. level, but has a horizontal area of from 150,000 to 400,000 sq.ft. below the 250-ft. level. It normally dips at from 35 to 55 deg., but above the 710-ft. level the northerly end turns flat and projects horizontally into the gneiss.

A very large area, 400 ft. long and from 400 to 700 ft. wide from foot to hanging, is minable up to the 250-ft. level. This area averages only about 40 per cent ore, but the sulphide in the area is high-grade and the whole area can be mined profitably. Below the ninth level the body has a normal dip. The Levack orebody occupies a shear zone near the norite-gneiss contact, but is all in the gneiss 40 to 200 ft. from the norite. Levack, like the other mines, gives the impression that the orebody was formed by sulphides injected into a fracture or shear zone.

The ore is hoisted through a central inclined shaft in the footwall. Levels are opened at 120-ft. vertical intervals. The orebody is mined by leaving 40-ft. continuous rib pillars, and stopes 100 ft. wide are mined out between pillars by shrinkage mining. A main haulage drift is driven parallel to the strike through the center of the ore if the dip is steep, or in the footwall if the dip is flat. Two crosscuts at 50-ft. centers are driven across the ore and boxholes put up on alternate sides of the crosscuts at 16-ft. centers.

Congestion at the footwall was removed by mining the footwall first, leaving a small central pillar, and drawing the stope clear of the footwall ore, then mining the stope from foot to hanging in successive slices. The stopes were at first mined 100 ft. wide, but latterly a narrow rib was left along the center to support the 100-ft. roof during the stoping period. This rib is weakened with break-throughs to insure its crumbling when the stope is drawn.

A study was made of the large area of gneiss and ore to see if it would pay to honeycomb this area with raises and mine out the ore only, but this was abandoned in favor of low-cost mining of the entire area, sorting the ore by a combination of magnetic belts and hand sorters, and selling the rock to the railways as ballast. This large area had a dome-shaped top and an irregular bottom. It was opened at the 250, 350, 470, and 590 levels, and the irregular bottom will be opened by drifting at the 710 ft. level. Most of this area was mined by shrinkage from the 590-ft. level up to the top of the ore. In addition to the 40-ft. pillars, a large central pillar 100 ft. wide was left at right angles to the 40-ft. ribs, and the area was finished off at the top like a domed cathedral, pillars being widened to support and leave a series of arched domed roofs. The narrow support ribs were carried up the entire distance of over 300 ft. and were satisfactory supports for the stope roofs. These were weakened to draw with the ore.

To Have Motor Haulage

This systematic laying out of the mine makes mining very simple. Drifting, raising, and boxhole work is contracted. Little supervision is required in the stopes, as the day's work is self-evident. About 80 tons per drill shift are broken in stopes and 35 drills are able to maintain development and break about 80,000 tons a month. About 250 men underground produce 2,500 tons daily. The haul has been short, so tramming has been by hand, by Granby-type cars, but motor haulage will be used in the future. Equipment and plant have a capacity of about 3,000 tons a day. Levack has an excellent surface plant, and a carefully designed rock house to carry on efficient sorting of rock and low-grade out of the material that is hoisted to the surface.

Garson mine has been in operation for 23 years. It is smaller than the other three operating mines and normally operates on a production basis of about 1,600 tons a day. This property has a central vertical hoisting shaft and an inclined escapement shaft. Levels have been opened at 100, 200, 300, 400, 600, 800, 1,000, 1,200, and 1,400 ft. Substantial reserves remain in the 600 to 1,000 zone, and extensive areas of ore have been opened at 1,200 and 1,400 ft.

Garson Has Abnormal Dip

Garson mines a series of bodies with a somewhat complex relation. The main ore zone has a northeast - southwest strike, and dips southeast at about 55 deg., and the dip is still definitely in this direction at the deepest level, the 1,400. This abnormal dip is apparently due to sharp folding in the norite-quartzite and norite-greenstone contact. This main zone has the shape of an arc approximately one-quarter of a circle. The dip is to the center of the circle; the hanging wall occupies the inside of the arc. Along this zone the ore is irregular in width, pinching out vertically and horizontally at intervals, and opening to widths of over 100 ft. between pinches. Four other zones contain extensive ore areas: A northwest zone, Orebody 16, an east-and-west zone with vertical walls at the southerly limit of the main zone, and a similar parallel zone at the northeast end of the main zone.

Three bodies have been mined along a radial zone outside the main zone, called the northwest zone. Orebody 16 has been mined down to the 800 level and is a high-grade veinlike body outside of the main zone, with strike and dip similar thereto. The two vertical shear zones with east-and-west strikes and nearly vertical walls have been important sources of ore. In these the ore rakes east. The southerly zone contained only a short orebody near the surface, but the ore zone in this is over 700 ft. long at the 800 and 1,000 levels.

Widths vary from pinches to over 100 ft. The northerly zone was first found to be important at the 800, and had a width of 20 to 100 ft. and a length of over 600 ft. up to the 600 level. Its importance above and below these levels has not been determined, although the minable area appears to diminish thereabouts. At Garson the various bodies are irregular, and the unraveling of the ore zones at each level usually takes from two to three years. The levels are opened by entering the ore areas, section-cutting the shrinkage-stope sill 25 ft. above the level, and advancing haulage drifts and boxholes as soon as sufficient ore area has been defined. At each level the diamond drill is used to complete the examination of an area approximately

1,000 by 1,000 and test all the area not opened by sectioning. The stopes are all watched daily for irregular enlargements and possible ore, and the walls are test-holed frequently.

Mining is all done by shrinkage. The backs are all strong, and areas several hundred feet long up to 100 ft. in width stand open. The system of haulage drifts below the stopes is carefully planned, and boxholes are placed to draw stopes to maximum advantage. Mining at the 200-ft. level involves some accumulation of ore on the footwall not readily drawn, but this difficulty is not sufficient to warrant the expense of intermediate levels. The stopes can all be drawn clear of ore when mining is completed, as the backs are strong and any footwall bays can be cleared after the shrinkage ore is drawn. The pinched-out areas in the orebodies in the upper levels have been sufficient to support the back, and no pillars have been left. A narrow floor at the 400 level has been left and the mine has been filled with the rockhouse waste above this level. Later, the lower levels may be filled with no great difficulty. Pillars are left in the lower levels where pinched-out areas do not give sufficient support.

This article is intended to describe the general conditions existing at the four operating mines of the company. Details of practice at the Frood, Creighton, and Levack are covered in separate articles that appear in the following pages of this issue.

■ ■ ■

MINING AT CREIGHTON

—Ralph D. Parker

Superintendent, Frood Mine

IN 1856, Salter, a surveyor, running base and range lines between Lake Nipissing and Sault Ste. Marie, noticed a variation of his magnetic needle, "from 4 degrees to 14 degrees westerly." Although not a geologist, Salter recognized the significance of this marked and extended attraction, and meeting Murray, a geologist, gave him particulars of the exact locality. Murray, following up Salter's hint, unquestionably walked over and examined the long gossan-stained ridge, at the foot of which, in later years, one of the world's greatest mines was discovered.

It was not until 1885 that two prospectors, Metcalf and McAllister, on the lookout for copper properties, applied for lots in the townships of Creighton and Snyder, and brought about the rediscovery of the great Creighton deposit. In 1885, the Canadian Copper Company obtained a transfer of rights of Metcalf and McAllister, in the lands for which they had applied, and in 1887 patent rights were issued to that company.

When the Algoma Eastern Railway was extended to the mine, in 1900, stripping was commenced, and the first shipment was made from Creighton to the smelter in Copper Cliff in August, 1901.

Many writers have discussed the origin of the ore. The various theories, as mentioned by Mr. Nicholls in his article, may be divided into two classes: (1) magmatic segregation, and (2) deposition from solution along zones of crushing and faulting. Geological work at Creighton has disclosed facts that indicate the origin of the ore by its intrusion in molten condition along planes of shearing in the footwall adjacent to the norite hanging wall, and in the norite itself.

The Creighton mine orebodies occur along a shear zone where the norite hanging wall forms a bulge into the footwall. This norite bulge continues at depth and bears the same relation to the orebodies throughout. The main orebody, which extends from the surface to the 20th level, is a contact occurrence of massive pyrrhotite carrying 1 part copper and 2½ parts nickel. Inclusions of rock are abundant below the 16th level, where an intrusion of greenstone forms the hanging wall of the orebody. (Fig. 1.) The west orebody lies in the footwall granite and extends from the 16th to the 28th level. This orebody consists of pyrrhotite, chalcopyrite, and pentlandite, chalcopyrite predominating, rock inclusions forming 25 per cent of the tonnage. The ratio is 3.5 parts copper to 2 parts nickel. (Fig. 1.) The north orebody extends from the 18th level to below the 50th level and lies in a shear zone in the norite. Massive pyrrhotite is the dominant mineral, with inclusions of norite, carrying 1 part copper to 3.5 parts nickel. (Fig. 3.)

The mine was first worked as an open pit, from the surface. Later, when increasing depth made this system dangerous, underground methods were adopted. At present, all development and stoping layouts are quite definitely determined by diamond drilling.

Four shafts have been sunk up to date:

No. 1, a three-compartment shaft at an incline of 59 deg., was used to handle ore during the earlier operations in the open pit and dry-wall stoping. It extended to the 5th level only and has since been dismantled and worked out.

No. 2 shaft, of four compartments, was sunk at an incline of 47 deg. and bottomed on the 12th level. The top 200 ft. of the shaft passed through a section of the main orebody and is now being mined out.

No. 3 shaft was sunk at an angle of 55 deg., a total incline distance of 2,376 ft., or to 86 ft. below the 30th level. It has five compartments, which are 5 ft. 10 in. by 6 ft. 6 in. in the clear. Two compartments are equipped for handling ore, two for men and supplies, and one compartment is for ladder, pipes, and electric cables. (Fig. 1.)

No. 4 shaft, an inside shaft, was sunk at an angle of 50 deg. and in the footwall of the North orebody. It is approximately 1,400 ft. northwest of No. 3 shaft and was sunk from the 20th level to 138 ft. below the 40th level, an incline distance of 1,870 ft. It has five compartments, two of which are for skips, one of which is a cage, one cage counterbalance, and one pipe-, cable-, and ladder-way. (See Fig. 3.)

A main crosscut is driven from the shaft out toward the orebody. From this crosscut drifting is begun parallel to and at a convenient distance in the footwall of the orebody. These headings or main haulage drifts are extended to the limits of the orebody and where orebody widths warrant, crosscuts are turned off every 75 ft. These crosscuts are parallel to one another, following the center line of the pillars and driven to within a few feet of the hanging wall. Chutes are raised from each crosscut

and are spaced at intervals of 15 ft. on alternate sides. (Fig. 2.) Footwall raises are driven on the center line of the pillar and on the contact to the level above. These footwall raises explore the footwall and serve as manways and as a means of ventilation for the stopes, to be carried up on either side. (See Fig. 4.)

From the footwall raises, any irregularities in the footwall are established, and from this information the locations of footwall chutes and branching ore passes are laid out. Stope ore passes are driven in the footwall and on the line of pillars. Branches from the main pass are taken off at intervals, so that chutes from the branch, when broken through into the stope, will not have a greater horizontal span than 30 ft. (See Fig. 4.)

A series of raises, 8x10 ft., are driven in the footwall between all main haulage levels. The raises are started from the sides of station crosscuts, a point for the brow of the control gates being carefully determined, and continued from this point to the level above at an angle of 65 deg. This forms a continuous ore pass, into which ore is dumped from the haulage levels and delivered to the crushers below. The ore is controlled on each haulage level by bent finger rails and at the crusher by a baffle gate. (Figs. 1, 3, and 9.)

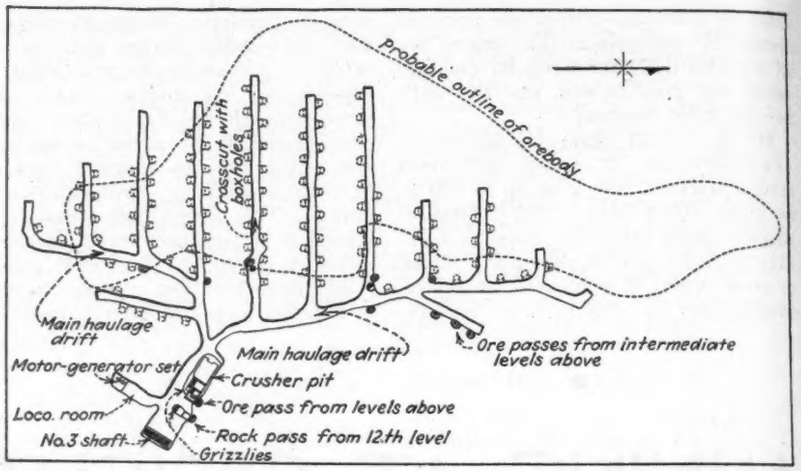


Fig. 2—Plan of fourteenth level

Waste rock during the last few years has been hoisted from the individual level on which it was produced. This has been done through small waste pockets cut on both working shafts and just below the shaft stations. A simple steel-lined wooden chute for loading into ore skips was used in both instances. Waste produced above the 30th level was hoisted direct to a waste bin on surface through No. 3 shaft. Waste below the above-mentioned point was hoisted to the 23d level by No. 4 shaft, transferred to No. 3 shaft, and then hoisted to surface. (Note detail in Fig. 9.)

However, since the adoption of cut-and-fill and square-set stoping methods, waste rock has been much in demand, and for many months past all waste produced in the mine has been utilized for back-fill purposes. Anticipating a growing demand for fill, a series of fill-supply raises are now being driven. For supplying the North orebody, a fill raise adjacent to No. 4 shaft, driven at 65 deg. from the 40th level to the 23d level, is under way. Control gates are to be installed on all main haulage levels and the raises adapted so that surplus waste on any individual level may be passed to a point of demand below.

Current development waste being inadequate, a fill supply raise is also under way from the 23d level to surface. This raise is going up in a manner similar to the one mentioned in the foregoing but adjacent to No. 3 shaft, and is to hole through on surface so that crushed rock from the sorting plant can be fed directly into it. (Figs. 1 and 3.) Fill will be transferred across the 23d level in a manner similar to the method of ore transfer.

From the open-pit method, which was continued to a depth of 300 ft., production has progressed through various stages of underground quarrying, shrinkage stoping with dry walls, and shrinkage stoping with drifts mainly in ore (both shrinkage methods left round pillars supporting the hanging wall), to the present method of shrinkage stoping with main drifts in the footwall, crosscuts in ore, and the use of rib pillars. The last two years have also seen the

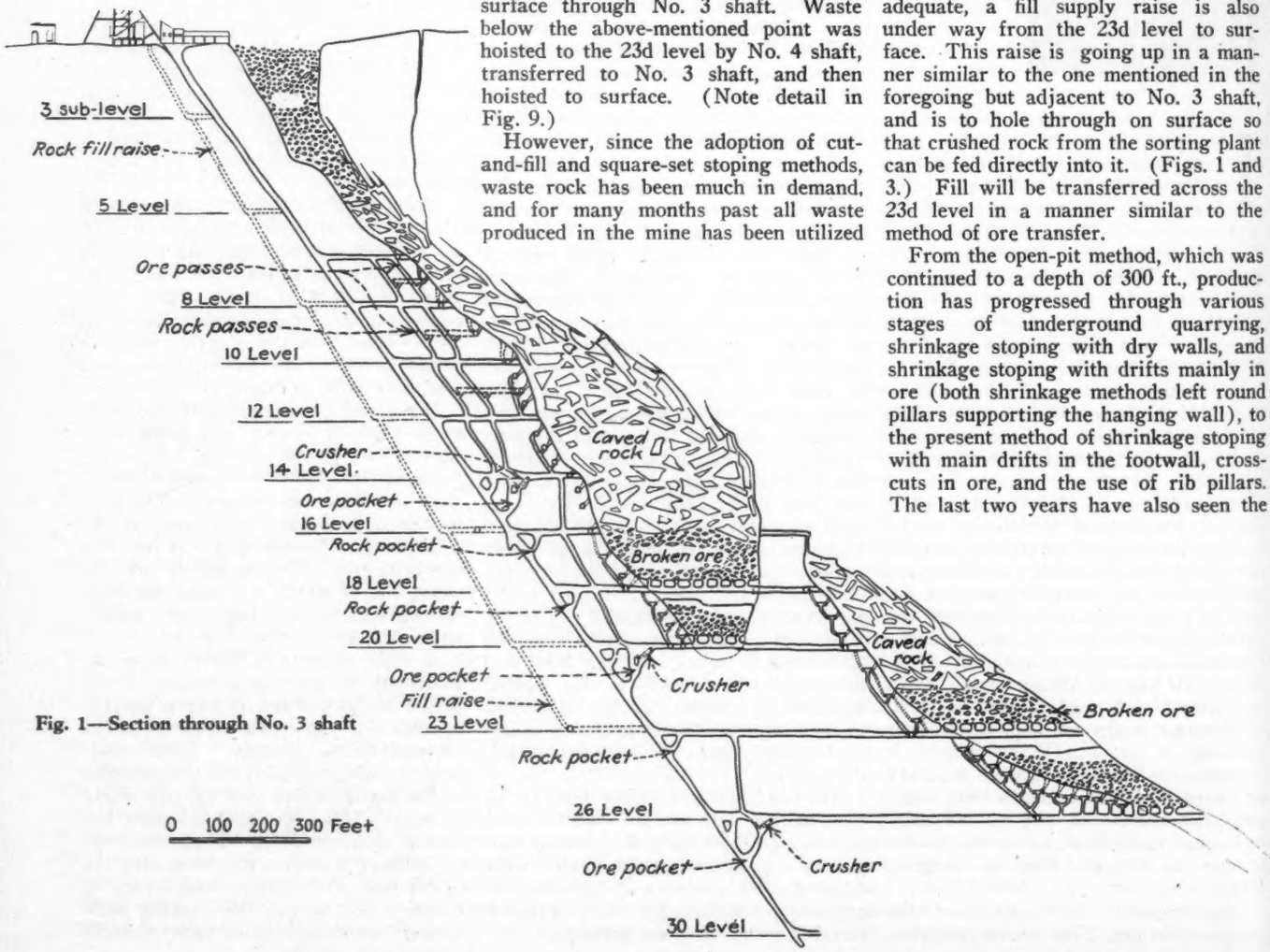


Fig. 1—Section through No. 3 shaft

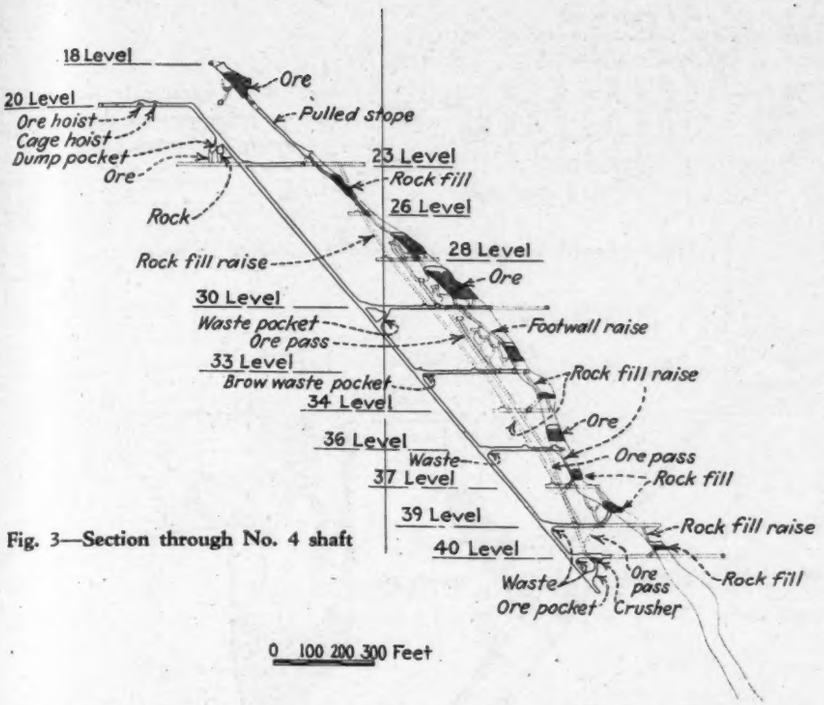


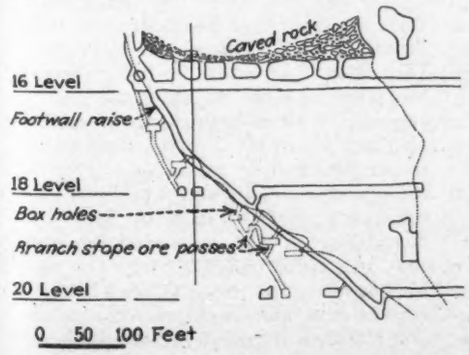
Fig. 3—Section through No. 4 shaft

adaption of cut-and-fill and square-sets to special conditions.

The stopes extend across the orebody from footwall to hanging wall (Fig. 5), so their length varies with the width of the orebody, which, in its wider sections, is between 200 and 250 ft. They are cut 50 ft. wide, and to provide a means of support to the back and hanging wall, solid rib pillars of ore, 25 ft. wide, are left standing between adjacent stopes (Fig. 4). These pillars run parallel to and are vertically above the center line of their respective crosscuts on the main haulage level. (Fig. 6.)

Floor cutting is begun 25 ft. above the level elevation by driving headings along the pillar lines from one chute to the next. These headings are then connected across the stope, and slabbing or slashing continues toward the hanging wall. Benches are arranged so that broken material is thrown by the blast into the nearest chute. Thus, a 25-ft. sill floor is left and boxhole chutes, driven up from both sides of the crosscut through this sill, provide the means of withdrawing the broken ore from the stopes.

Fig. 4—Cross-section through pillar



The next stage in the cutting of the stope is accomplished by raising the elevation along the footwall and carrying a breast toward the hanging wall. Stoping progresses from footwall to hanging wall, carrying a bench 8 to 12 ft. high and of full stope width. Broken ore is drawn in advance of the benches, and a height of from 6 to 8 ft. below the back is maintained from the footwall to the working face. This affords comfortable headroom and an opportunity for inspection and scaling of the back. (Fig. 5.) As successive benches are taken and the footwall section is raised, holes are driven through to the footwall raise on the center line of adjacent pillars to serve as manways to the stope.

When the ore has been broken to a convenient distance from the floor of the stope above, the floor can be taken out any time after the stope directly above has been pulled, and efforts are made to arrange operations so that this will be done immediately.

When ready to carry through, a section near the hanging wall is thinned to about 14 ft., a cut is blasted through, and the rest of the section is drilled off with vertical holes and blasted. The entire floor is then removed by retreating in similar stages toward the footwall. (Fig. 5.) Solid pillars of ore capped with waste and flanked by broken ore are now left standing. (Fig. 6.)

Pillar recovery consists of driving and square-setting as advanced, with 10x10-ft. raises at 30-ft. centers along the center line of the pillars. These raises are extended to within 10 ft. of the upper level (in odd cases through to the level to act as a manway down) and are started from the tops of smaller raises, in the sill floor of the pillar, which are connected by drifts. Manways are thus provided into the pillar workings, and serve as chutes for the extraction of the ore broken in driving the raise.

Cuts are drilled at intervals in the raise, into the stopes on either side, and drift rounds taken in each of the other two sides to provide faces to which to break. "Drilling-off" operations begin when all minor blasting operations are completed. (Fig. 7.) Sections of a pillar, or whole pillars, are blasted instantaneously, electrically. (Fig. 8.) The largest blast so far was one of

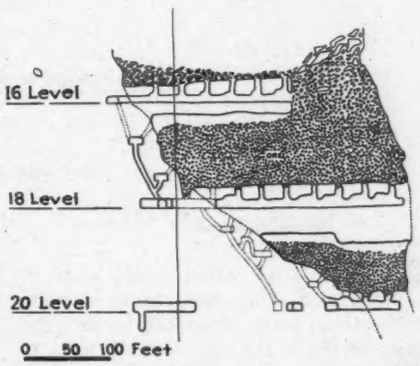
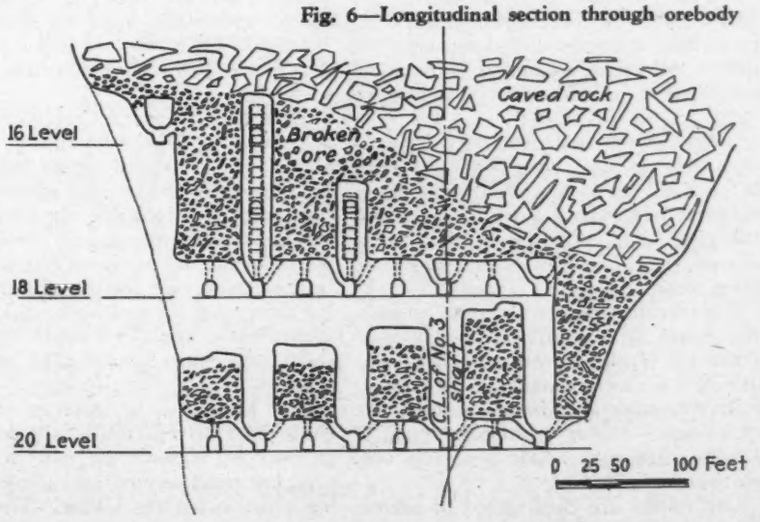


Fig. 5—Cross-section through stope

Fig. 6—Longitudinal section through orebody



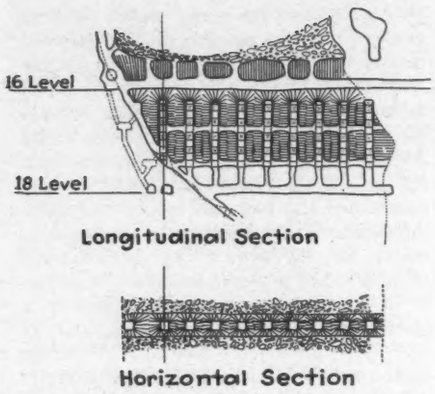


Fig. 7—Section through pillar, showing raises and drill holes

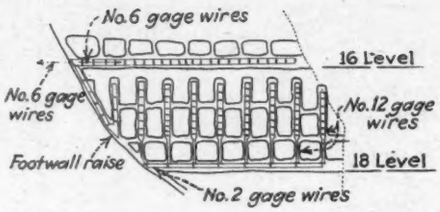
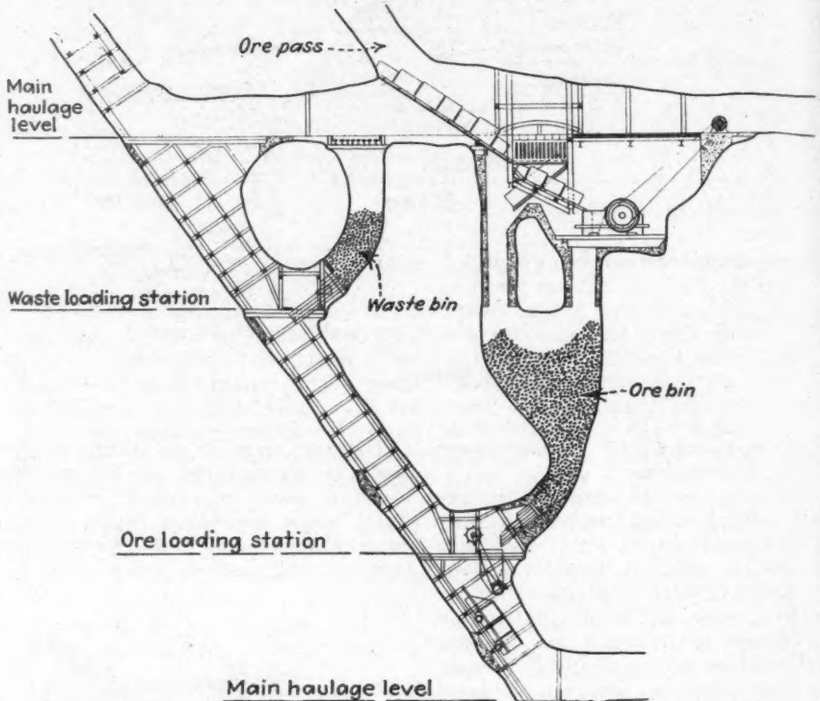


Fig. 8—Longitudinal section through pillar showing detail of wiring for electric blast

Fig. 9—Section through crusher and skip-loading pockets



9,800 holes, which broke 177,600 tons.

Shrinkage stopes in narrow orebodies are developed from drifts in the footwall or, where grade and inclination warrant, from footwall branch raises, with boxholes off both. (Fig. 3.) No crosscuts are driven through the orebody for chutes and pulling purposes. Stoping is carried longitudinally with the orebody from rib pillars 30 ft. wide and placed at intervals depending upon conditions. Footwall raises are driven similarly to the practice outlined for mining wide orebodies, and serve the same purpose. Almost always, when this method has been adopted, the dip of the ore has been sufficiently steep so that footwall branch raise development was not required.

Conditions arose during the progress of both of the aforementioned stoping arrangements which made impossible their further economical continuance, and which could not have been foreseen from results of similar work. Hazardous ground, irregularities of the deposit, rock inclusions, and rock disposal have been cause for the adoption of cut-and-fill and square-set stoping methods. So far, only a comparatively small tonnage has been derived from these methods, and therefore they need not be dealt with further.

On intermediate levels, and during the early stage of level development, 16-cu.ft. hand-trammed side-dump cars are used. All other tramming is done by locomotives in 56-cu.ft. Granby-type cars.

Twelve 5-ton storage-battery locomotives are in use, each equipped with 66 Edison cells to a battery. These batteries have about a six-hour normal charging time, utilizing 10 kw. to a charge, and have an average life of seven years.

For transferring ore and rock between No. 3 and No. 4 shafts on the 23d level (transfer level), a 6-ton trolley locomotive has been installed. This locomotive handles a train of fourteen 56-cu.ft. cars. Power is supplied from a 37½-kw., 250-volt, motor-generator set, on the same level.

Car tipples are constructed of timber fitted with steel wheel tread, cast in sections 6 ft. long, the curved surface of the tread being developed so that the dump wheel of the car is at all times at right angles to the plane of the tread.

Track gage is 24 in. Twenty-five-pound rails are used on intermediate levels, and 40-lb. rails for locomotive haulage. All tracks are laid on 0.4 per cent grade with a minimum curve radius of 30 ft.

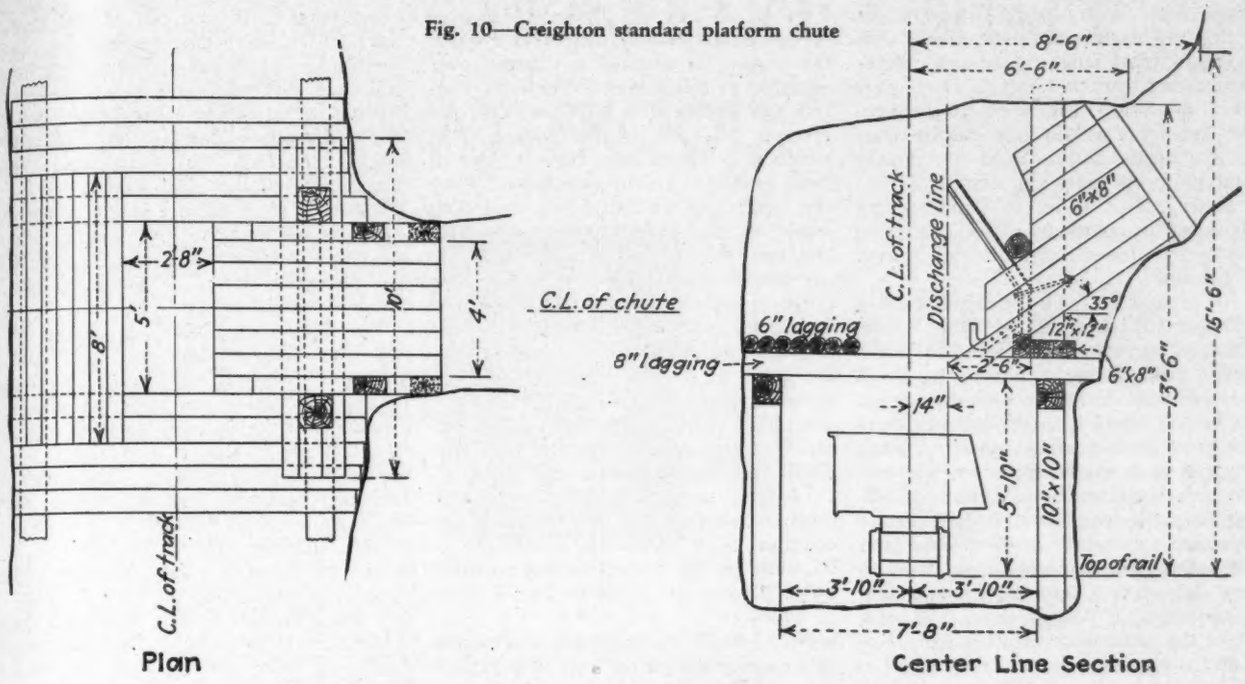
Details of standard Creighton chutes are shown in Figs. 10 and 11. Fig. 10 shows the standard stope chute of wooden construction. Its essential features are its height and the location of the brow point with a funnel effect upward, so that large pieces can jam only in the chute; also, the use of a platform for safety and ease of loading. During 1929 the average tonnage per trammer-shift from chutes of this kind was 61.6 tons.

Fig. 11 shows the standard concrete chute used on practically all stope ore passes. Its features are ease of operation, low maintenance, and a safe working position for the loader. The average tonnage during 1929 from chutes of this kind was 146.2 tons per trammer-shift.

As all the production comes to surface through No. 3 shaft, every effort is made to effect rapid and safe handling of ore, materials, and men. The ore is hoisted to the rock house in 9-ton skips, working in balance through the first two compartments of the shaft. Men and material are handled in steel man cages, working in balance in the third and fourth compartments.

The ore hoist is of the Ilgner type, built by Wellman-Seaver-Morgan, with drums 12 ft. in diameter and 7½ ft. wide. One drum is keyed to the shaft, whereas the other is loose on the shaft and is provided with a multiple-tooth clutch, operated by an oil cylinder supplied by the accumulator by means of a lever on the operator's platform. The hoist motor has a normal rating of 1,800 hp. continuous at 550 volts and 40 deg. rise, at a speed of 66½ r.p.m. The motor-generator set consists of a direct-current generator, a wound-rotor induction motor, a 50-ton steel-plate flywheel,

Fig. 10—Creighton standard platform chute



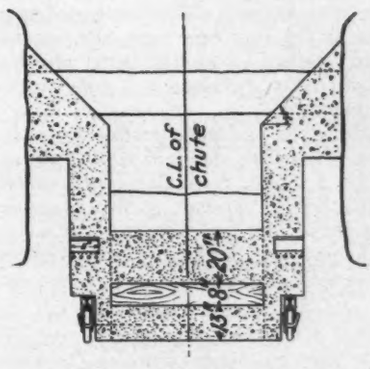
and a direct-connected shunt-wound exciter, all mounted on a common bedplate. On this hoist the cables are 1½ in. diameter, six-strand, sixteen-wire construction, of extra special plow steel.

The man and material hoist is a Nordberg two-drum machine driven through one reduction by a 350-hp., slip-ring variable-speed motor (alternating current) rated at 480 r.p.m. at full load. The drums are 7 ft. in diameter with a 4-ft. face and each is fitted with parallel-motion post brakes. Hoisting speed is about 1,100 ft. per minute. Ropes for this hoist are 1¼-in., six-strand, sixteen-wire, of special plow steel.

Skips are 9-ton capacity, and all steel, weighing 12,200 lb. Wheels are of manganese steel pressed on forged-steel axles. Bails are forged low-carbon steel and are annealed every six months.

Man cages are constructed of steel plate, riveted to trucks, and weigh 8,800 lb. empty. Wheels and axles are the same as on the skips. A screen door slides up and down the front (its weight being counterbalanced), entirely inclosing the men in a steel car. Cages have a capacity of 30 men.

Both skip and cage tracks are 4 ft. 6 in. gage. Rails are standard C.P.R. 85-lb., connected with angle splice bars,



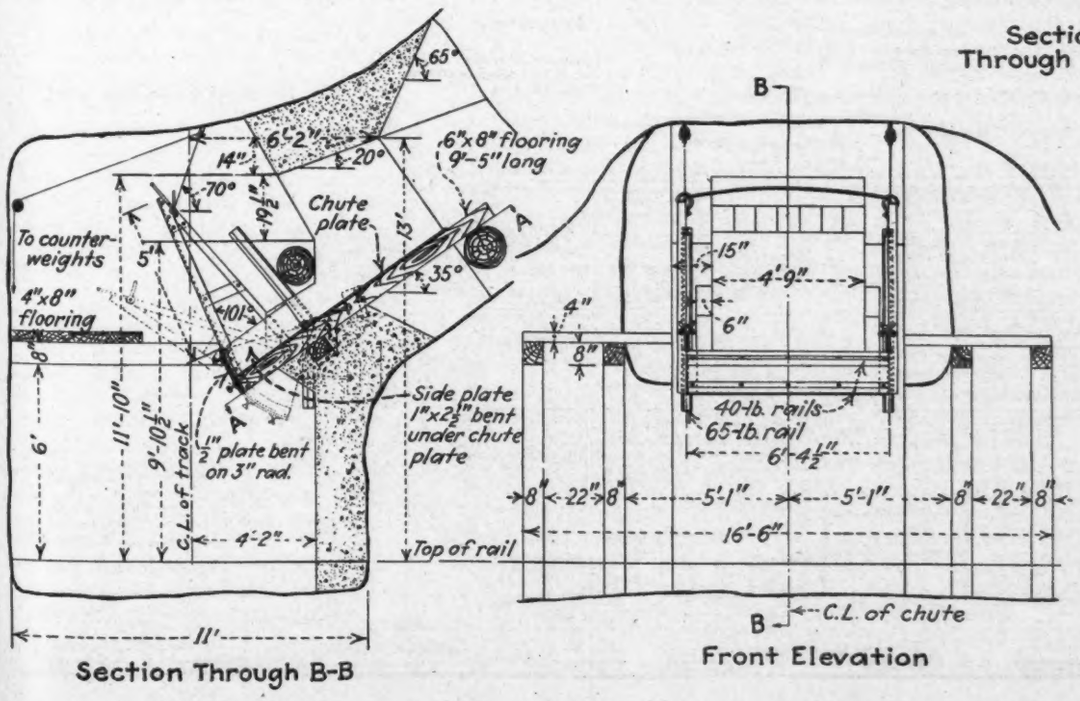


Fig. 11—Creighton standard concrete chute

track bolts with spring washers, tie plates on each sill, and spiked with ⅞x5½-in. track spikes. One anti-creeper is attached to each rail. A 24-in. gage track of 40-lb. rails is placed between the heavier rails in one of the cage compartments and is used to transfer haulage locomotives and cars.

Shaft rollers 6 in. in diameter are placed 60 ft. apart and offset 2 in. from the center line through the full length of the shaft.

All production from the north orebody is hoisted through No. 4 shaft to the 23d level and then transferred to No. 3 shaft. All hoisting equipment in No. 4 is in a hoist room on the 20th level.

The ore hoist is a Wellman-Seaver-Morgan double-drum electric, with drums 6 ft. in diameter and with a 4-ft. face. It is driven by a 250-hp., 2,200-volt, variable-speed motor through one reduction. One-inch rope of six-strand and seven-wire construction is used to hoist skips of 4 tons' capacity, at 800 ft. per minute. Wheels, axles, and bails are of the same material as used in No. 3 shaft.

The cage hoist is an Ottumwa double-drum 10½x14-in. air hoist with drums 4 ft. in diameter and a 3-ft. face. On both drums, ¾-in., six-strand, seven-wire rope is used. The one cage has a capacity of fourteen men, the second drum being counterbalanced by a weighted car traveling in a small compartment.

Both skip and cage tracks are 4-ft. gage. Rails are standard 60-lb., laid as in No. 3 shaft. A similar arrangement to that in No. 3 shaft is also used for transfer of cars and motors.

The positions of underground crushers and ore-loading pockets are shown on Figs. 1, 3, and 9. Broken ore from the ore pass and from the level on which the crusher is situated is dumped over separate grizzlies into a 30x42-in. Farrell jaw crusher set at 6 in., and the product falls into an ore pocket, from which it is loaded into skips. Four of these crushers are in operation. They are located at the 14th, 20th, and 26th levels on No. 3 shaft, and at the 40th level on No. 4 shaft, crushing all the ore above their respective levels. The crushers weigh 65 tons, with base and flywheels sectionalized for passing through the shaft. Water and grease are used to lubricate the pitman and journals, and cup grease is used for the jaw shaft. The crushers run at a speed of 235 r.p.m., and are connected to two 75-hp. induction motors.

Loading stations below each of the crushers mentioned in the foregoing are equipped with measuring boxes (Fig. 9), those on No. 3 shaft having a capacity of 9 tons, and those on No. 4 shaft of 4 tons.

No. 3 shaft is examined and necessary repairs are made once in every 24 hours. The minimum amount of time allotted to this work has been six hours. As no routine work is performed in the mine on Sundays, all major shaft repairs are done at that time.

A record through No. 3 shaft was made in April, 1930, when 156,832 tons was hoisted in 26 days of eighteen hours' each.

For drifting, crosscutting, stoping, and sinking, 3½-in. Leyner-type machines, mounted on 4-in. column bars, are used. All raising is done with self-rotated stopers. Steel is 1⅛-in. hollow hexagon. Sharpening is done on surface in a shop for that purpose, about 2,000 pieces being handled in and out of the shop daily. Five sharpening machines are in operation. Each has its own rack for dull steel, a furnace, and punch, thereby making a complete sharpening unit. Each sharpener handles only certain lengths of steel, thus minimizing the changing of dollies and gaging blocks. All steel is reheated in a single furnace. The bits are tempered by plunging into a tank of running water, and the shanks are tempered in oil. About 330 bits are sharpened per sharpener-shift.

The main rock house is a portion of the headframe, of steel and brick construction, with reinforced-concrete floors, and stands on concrete pillars directly over the railroad track on which the receiving cars draw the sorted product from the storage bins. The hopper-bottomed receiving bin into which the entire mine ore is dumped is at the top of the building. From this the ore is drawn off through a gate controlled by a rack and pinion and fed by 5-ft. diameter rolls, from which it falls into the upper-floor trommels. The oversize discharge from the top-floor trommel passes onto picker belts on the same floor; waste rock is taken out by the pickers and dropped down conveniently placed steel chutes into a sorted-rock storage tank. Ore remaining on the belt is carried to the end, where it drops into a 48x15-in. Farrell jaw crusher set at 2¾ in. All the crushed material passes over rail grizzlies with ¾-in. openings, and the undersize of the grizzlies goes direct into a dry-fines bin.

On the second floor, the oversize from the grizzlies under the crushers passes onto a short magnetic-pulley belt, with the magnetic ore traveling around with the belt and directly into the coarse-ore bin. The non-magnetic material drops onto a short picking belt, from which ore is picked by hand and then dropped

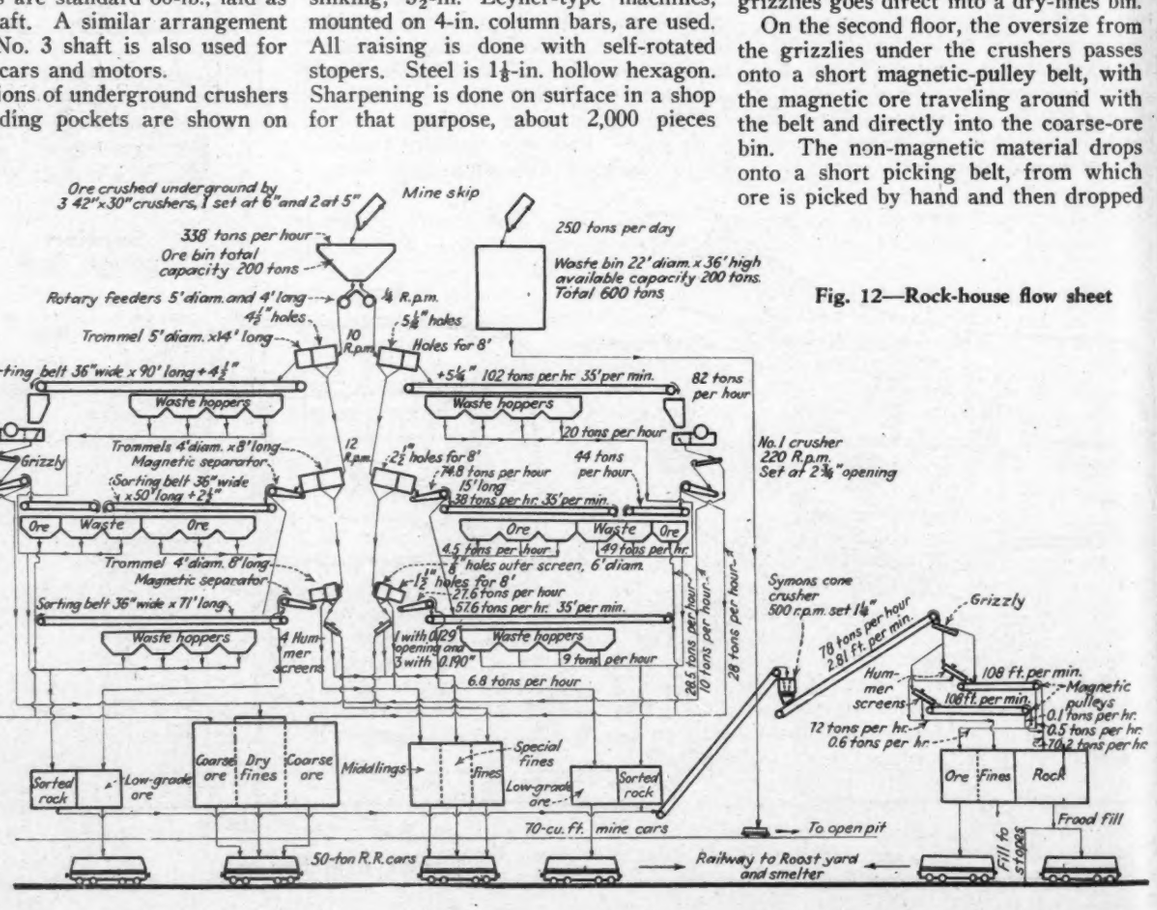

Ore crushed underground by 3 42"x30" crushers, 1 set at 6" and 2 at 5"
Mine skip
338 tons per hour
Ore bin total capacity 200 tons
250 tons per day
Waste bin 22' diam. x 36' high available capacity 200 tons. Total 600 tons
Rotary feeders 5' diam. and 4' long
¼ R.p.m.
4½" holes
5⅛" holes
Trommel 5' diam. x 14' long
10 R.p.m.
Holes for 8'
Sorting belt 36" wide x 90' long + 4½"
+5¼" 102 tons per hr. 35' per min.
82 tons per hour
Waste hoppers
No. 2 crusher 48"x15" crusher Capacity 125 tons per hour
20 tons per hour
No. 1 crusher 220 R.p.m. Set at 2¾" opening
Grizzly
Trommels 4' diam. x 8' long
Magnetic separator
12 R.p.m.
2½" holes for 8'
74.8 tons per hour
44 tons per hour
Sorting belt 36" wide x 50' long + 2½"
15' long
38 tons per hr. 35' per min.
Ore
Waste
Ore
4.5 tons per hour
49 tons per hr.
Trommel 4' diam. 8' long
Magnetic separator
1½" holes for 8'
6" holes outer screen, 6' diam.
27.6 tons per hour
57.6 tons per hr. 35' per min.
Sorting belt 36" wide x 71' long
Waste hoppers
4 Hummer screens
1 with 0.129 opening and 3 with 0.190"
9 tons per hour
6.8 tons per hour
28.5 tons per hour
10 tons per hour
28 tons per hour
Symons cone crusher 500 r.p.m. set 1⅛"
Grizzly
78 tons per hour
2.81 Ft. per min.
Hummer screens
108 ft. per min.
Magnetic pulleys
0.1 tons per hr.
0.5 tons per hr.
70.2 tons per hr.
72 tons per hr.
0.6 tons per hr.
Ore
Fines
Rock
Sorted rock
Low-grade ore
Coarse ore
Dry fines
Coarse ore
Middlings
Special fines
Fines
Low-grade ore
Sorted rock
70-cu. ft. mine cars
To open pit
Frood fill
Fill to stopes
50-ton R.R. cars
Railway to Roost yard and smelter

Fig. 12—Rock-house flow sheet

through chutes to a conveyor on the first floor and thence into the coarse-ore bin. Waste material left on the belt drops off the end into the waste tank.

Undersize, which passed the openings of the top-floor trommel, drops through hoppers into trommels on the second floor. The openings in this trommel are 2½ in. in diameter, and the undersize goes direct to the floor below. Oversize of this trommel passes onto a short magnetic belt, from which the magnetic material is dropped to the first floor and conveyed to the coarse-ore bin. Non-magnetic material drops onto a picking belt, from which ore is picked and dropped to the first floor to be conveyed to the coarse-ore bin. Waste left on the belt drops into the waste tank.

On the first floor the undersize from the second floor is again screened in a trommel; this, however, is a double screen with holes in the main section 1½ in. in diameter. The oversize goes onto a short belt with a magnetic head pulley, the magnetic ore passing onto the first-floor conveyor and then to the coarse-ore bin. The non-magnetic material drops direct into the low-grade ore bin. Undersize from the first-floor trommels is again sized by a second screen outside the main one. This outside section has ⅞-in. holes and the oversize from it passes to the middling bin. Undersize from the outside screen is passed to a battery of Hum-mer vibrating screens, the undersize from which is stored as "special fines" and the oversize product as "fines." Little or no hand sorting is done on the first floor. The conveyor traveling there carries sorted or magnetic ore, and only where the ore is highly siliceous is any further sorting done.

As 25 per cent of the ore hoisted is sorted out as waste, Creighton mine has become the source of back fill for the Frood mine as well as for its own fill stopes. Most of the waste, as sorted, is of a size too large for good handling as fill and contains a little sulphide.

Recently a secondary crushing and sorting plant has been built to do this fine crushing, and installations have been made to make a further ore recovery. A conveyor from the sorted-rock bin in the main rock house discharges into a 5½-ft. Symons cone crusher set at 1¼ in. This product is conveyed to a grizzly with 1-in. openings. Undersize from the grizzly drops onto vibrating screens, the undersize from which is taken as fine ore. The oversize of the grizzly and the screens both drop onto magnetic belts, where some hand sorting is done. Both magnetic and hand-sorted ore are dropped into a coarse-ore bin and the non-magnetic material is passed into a waste-storage bin. From this storage bin waste can be transferred either directly back into the mine or loaded onto railway cars and shipped to the Frood mine. About 8 per cent of this recrushed material is taken off as ore.

SINKING NO. 3 SHAFT AT FROOD

—*Allan F. Brock*

Operating Engineer

THE exploration of the lower levels of the Frood orebody, by deep boreholes drilled from surface, had proved ore to the 2,800-ft. level and indicated that the ore between the 2,000 and 2,800 levels was of sufficiently higher grade than the ore above to make it desirable to mine the lower levels first. Accordingly, No. 3 shaft was planned, the decision being to establish the bottom level at 2,800 ft., and to sink far enough below this level to make room for an ore pocket and skip-loading pocket, a total depth of 3,045 ft.

No. 3 shaft is 28 ft. 2 in. x 16 ft. outside the timbers, divided into four main compartments 14 ft. 4 in. x 6 ft. in the clear. No. 1 compartment is divided into a skipway 6x6 ft., a ladderway 3x6 ft. and a pipeway, 4 ft. 8 in. x 6 ft. No. 2 compartment is divided into a skipway 7 ft. 2 in. x 6 ft. and a service cageway 6 ft. 8 in. x 6 ft. Nos. 3 and 4 compartments are 14 ft. 4 in. x 6 ft. and are the material cageways. The excavation is approximately 18 ft. x 30 ft.

During the sinking operations, a cage operated in the skipway in No. 1 compartment. Guides for the sinking skip were placed in No. 2 and No. 3 compartments, on the center line of the shaft, so that the skips were in the center of the shaft. No. 4 compartment was used as a pipeway. The service cage was a single-deck cage approximately 5x5x6 ft. 6 in., equipped with safety dogs. It carried a load of ten men, or 2,000 lb. of material. The sinking skips were 4 ft. 9 in. x 4 ft. 8 in. x 3 ft. 5 in. and held 3 tons of broken rock (see p. 445). They were equipped with hoods and safety dogs and with 30-ft. extension guides, permitting them to be lowered directly to the bottom of the shaft.

The cage hoist was a single-drum Denver Engineering Works electric hoist, driven by a 250-hp. motor, the drum being 4 ft. 9 in. in diameter with 4 ft. 10 in. face, with capacity for 3,200 ft. of ⅞-in. rope in four layers. Rope speed was 600 ft. per minute. The skip hoist was a double-drum Wellman-Seaver-Morgan electric hoist driven through one reduction of gearing by a 500-hp. motor with a speed of 500 r.p.m., designed to handle a maximum load of 19,000 lb. at a rope speed of 1,500 ft. per minute. Drums were 10 ft. in diameter; width of face was 5 ft. 1 in. Capacity of drums, 3,200 ft. of 1⅛-in. rope in two layers.

Skips were operated in balance. When hoisting men the rope speed was reduced to 750 ft. per minute by man-safeties on the Lilly controllers.

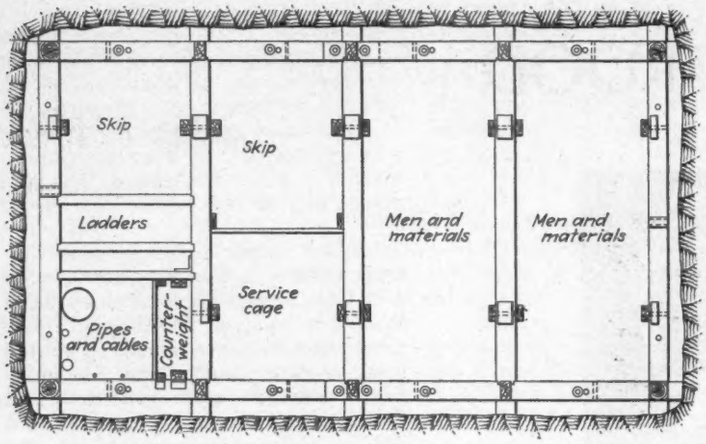
The sinking headframe and rock bin, constructed of timber, was 90 ft. high from the collar of the shaft to the sheaves. It was designed to fit inside the steelwork of the permanent headframe, so that the permanent headframe could be erected without interrupting sinking operations.

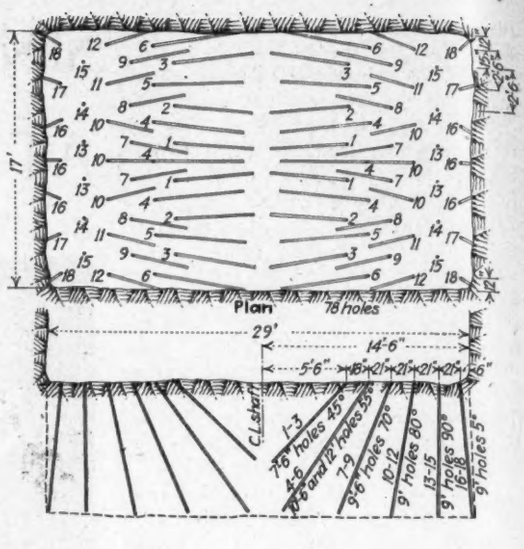
Two 2,500-cu.ft. rope-driven Ingersoll-Rand compressors supplied the compressed air.

Work in the shaft started on Sept. 1, 1926. From then to Dec. 12, 1926, 53 ft. of shaft was sunk, the concrete collar poured, the sinking headframe erected, and the cage and skip hoists were installed. On Dec. 12, 1926, sinking was resumed and continued without interruption until March 27, 1928, when the shaft had reached a depth of 3,043 ft. The sinking crew was made up of a leader, a pointer, a pipeman, and a crew of 25 sinkers per shift. Work was carried on three shifts a day and seven days a week. "C. P. 5" drills mounted on spring handles and fitted with 1-in. hexagonal chucks for 1-in. hexagonal steel were used throughout the sinking of the shaft.

The air header was made from a piece of 10-in. pipe, with 24 bosses welded on the sides and tapped for 1-in. hose connections. A 4-in. cotton-covered flexible air hose connected the header with the pipe line. The water header, constructed in the same way as the air header from a 6-in. pipe, was connected to the water line by a 2-in. fire hose. Both the air and water headers had chains attached for slinging them from the shaft timber. When rigging up to drill they were sent down in the skip, the chains attached to the

Below, plan of No. 3 shaft; at right, section of No. 3 shaft round





center divider of the last set, and the skip was lowered from beneath them. The headers hung in the center of the shaft and within easy reach of the sinkers standing on the bottom. Only short lengths of hose were necessary to connect up the drills.

A typical round used is shown on the accompanying sketch. The total number of holes drilled varied from 78 to 84. The inner cut was drilled with 7-ft. steel, the outer cut with 11- to 12-ft. steel, and the square-up holes with 10- to 11-ft. steel. Twelve drill runners, six on each side of the center, drilled each line of holes across the shaft in succession, starting with the line forming the inner cut. The other four runners, two at each end of the shaft, drilled the outside lines of square-up holes.

The cuts were blasted first, using 1-in. diameter 75 per cent Polar Forcite. After blowing the smoke, the sinkers shoveled out the cut and loaded and blasted the square-up holes, using both 75 per cent and 40 per cent Polar Forcite. On reaching the bottom, when shoveling out the round, a sump was drilled at the center of the shaft against the hanging-wall side. The sump was blasted as soon as drilled and the broken rock cleaned up with the rest of the round.

Sinking Data

Average rate: 199.3 ft. per month.
Average length of round: 8.8 ft.
Average time to complete a round: 33 hours.
Record month sinking: 232 ft.
Pounds of powder per foot of advance: 75 per cent, 50.3 lb.; 40 per cent, 18.5 lb.; total, 68.8 lb.
Rock broken per foot of shaft: 52.5 tons.
Rock broken per round: 462 tons.
Total broken in the shaft: 153,000 tons.

Time Distribution

	Per Cent
Drilling	15.24
Blasting	5.45
Blowing smoke	8.46
Shoveling	55.52
Rigging	6.16
Scaling	5.74
Timbering delay	1.27
Other delays	2.16

The shaft timbering was done by a special crew consisting of a leader and ten timbermen, called out when necessary to hang a set. Sets were hung while the sinkers were shoveling out the round.

Wall plates were framed in two pieces, which were spliced when they were put in place. Each piece was bored at one end for a bridle and at the other for an eyebolt. The two half wall plates and the end plate covering Nos. 3 and 4 compartments were sent down under No. 3 skip. The half wall plates and end plate covering Nos. 1 and 2 compartments were sent down under the service cage. No. 3 skip was stopped at the surface after being dumped, a timber slung under it on a bridle sling, and lowered to the timbermen. The lower end of the timber was fastened to the wall plate of the set above by an eyebolt sling, and the skip lowered until the timber assumed a horizontal position, when it was swung into place and the hanging rods were put in. Then the slings were taken off and the skip was lowered to the sinkers, who filled it. The other half wall plate was sent down on the next trip. When both wall plates had been hung and spliced together, the end plates were sent down and fastened in place.

While this work was going on, the shovelers moved from one side of the shaft to the other to avoid being under the timber as it was being hung. The rest of the set, the dividers and posts, was sent down and put in position while the sinkers were at the surface for lunch. Blocking was done after the sinkers were back at work. To prevent blocks from falling while they were being wedged, a 3½-in. staple was driven into the top of the block and a ⅛-in. chain, with a harness snaffle on one end, was hooked into the staple and fastened to the wall plate above. Every fifth set, the timber crew came out while the sinkers were drilling, took off the short guides, and replaced them with the standard 35-ft. guides.

In addition to the timber crew, a brattice crew of two timbermen worked day shift, a lagging crew of two on each of the three shifts, and a Cement-Gun crew of two timbermen worked when the sinkers were drilling. With this arrangement, timbermen were always available to repair timber damaged by blasting. Timberman shifts per set averaged 17.6.

During the sinking of the shaft only one man was seriously injured. His leg was fractured by a large piece of rock rolling against it. J. P. Hussey superintended the shaft sinking, and to him the credit is due for the safe and efficient manner in which the work was carried out.

■

Special type of car for explosives, and timber, ready to go underground at Frood

MINING THE FROOD OREBODY AT DEPTH

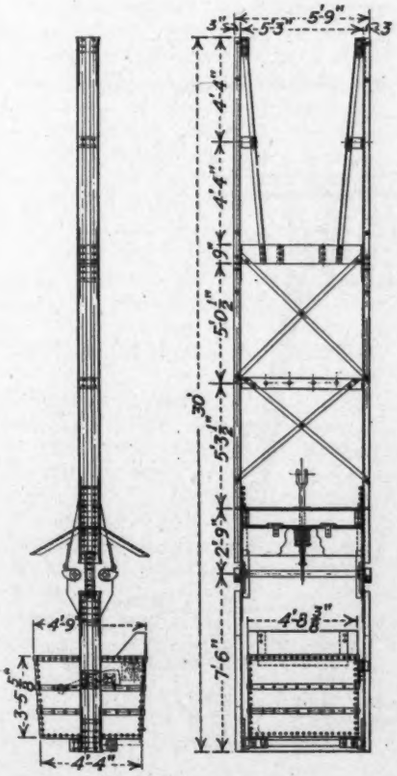
—*Herman J. Mutz*

Assistant Superintendent of Mines

THE Frood mine lies about 2½ miles north of the city of Sudbury, Ontario, in Lots Nos. 6 and 7 of the Sixth Concession, Township of McKim. It is situated on the southwestern third of a mineralized zone which ends about 2 miles to the northeast, at the Stobie mine. The gossan occupies a prominent ridge, and a series of parallel ridges with swamp and muskeg lying between them flank it on either side. To the northwest lie higher granite hills, and to the southeast a higher ridge of arkose. The maximum difference in relief is not over 200 ft. The general elevation is 1,000 ft. above sea level. Rock outcrops are numerous and the glacial débris found is seldom more than 5 ft. thick.

The Frood deposit was among the first discoveries in the district. It was staked in May, 1884, but not until 1889 was it a producer. From 1889 to 1903 about 100,000 tons of ore was mined from open pits. During the years 1913-1914, about 175,000 tons of ore was mined on the 200 and 300 levels from No. 1 shaft. In 1925, a deep-drilling campaign was started. Higher-grade ore was found at depth, so those interested decided to develop the area between the 2,000 and 2,800 levels for mining.

Details of No. 3 shaft-sinking skip



No. 3 shaft was completed in March, 1928. Excavations for the foundations of the surface plant at No. 3 shaft, including hoist and compressor house, warehouse and drill shop, collar house, machine and electrical shop, change house, and office building, were started in April, 1928. The plant was completed and most of the machinery installed by March, 1929.

During this period stations had been cut on the 1,200, 1,600, 2,000, 2,400, and 2,800 levels and crosscuts driven to the orebody. Crosscuts on the 1,600, 2,000, 2,400, and 2,800 levels intersected the orebody in January, 1929.

Mond Nickel Company had sunk No. 4 shaft to the 2,000 level. Development work was started on the 1,400, 1,700, and 2,000 levels and boreholes were put down from crosscuts in the hanging wall on the 2,000 level, which intersected the orebody on the 2,800 and 3,100 levels. This drilling indicated the existence of ore containing higher copper content at depth. The shaft was then continued to a depth of 3,345 ft. and development work started on the 2,800 and 3,100 levels. Some stopes had been started on these levels when the amalgamation of the two companies was completed. This work was stopped and connections were started for No. 3 shaft workings.

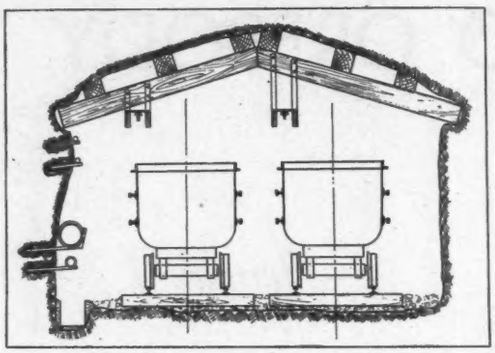
The walls of the Frood orebody are metamorphosed sediments and greenstones. These form a part of a formation known as the Sudbury Series, and are equivalent to the Timiskaming Series of the Cobalt district, which are below the Lower Huronian. They are the oldest rocks in the district. The orebody is next in point of age. It is contemporaneous with the Sudbury nickel eruptive, and belongs to the Keweenawan Series. A younger granite is found several hundred feet in the hanging wall, but it is not found in any of the underground workings, and apparently has had no disturbing effect on the deposit.

The dip and strike of the orebody are parallel to the bedding of the surrounding sediments. The general trend is N. 35 deg. E., with an average dip of 65 deg. to the northwest. In this deposit, the principal ore minerals are chalcopyrite and pentlandite. Pyrrhotite is present in amounts exceeding the other two combined, and is the carrier of nickel, as minute particles of pentlandite, in physical combination with it.

The horizontal cut-and-fill method was adopted as most suitable to the conditions of the orebody on the lower levels. This area was known to be of a grade that required a method permitting the highest extraction. Drilling had disclosed that considerable rock was present in certain zones, a condition that pointed to the possibility of underground sorting. Likewise, the drill holes had proved the presence of barren horses of rock within the orebody, and had also indicated that the footwall and hanging wall were very irregular. It was felt that close filling would be essential to leave the orebody above the 2,000 level intact and in condition to mine later.

During development, the main haulage crosscuts on the 2,000, 2,400, and 2,800 levels were driven 15 ft. wide by 8 ft. high, the roof being supported by the saddle-back method of timbering shown in Fig. 1, p. 446. These crosscuts are double-tracked at shaft stations, ore dumps, and storage tracks near the footwall of the orebody. Fig. 2 shows a section on the main crosscuts driven on the 2,200 and 2,600 levels. These drifts were driven 9x9 ft. The main crosscuts from No. 3 shaft on these levels were extended to the hanging wall of the orebody, and development for mining operations was started therefrom.

Footwall drifts 9x9 ft. (Fig. 2) were started, on each of the mining levels, from the main crosscuts at a point about 65 ft. from the orebody, and driven



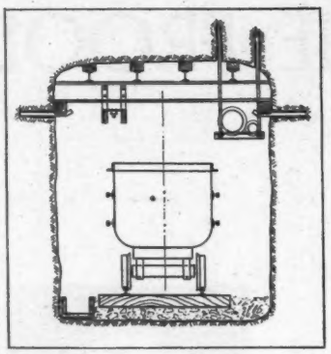


Fig. 1—At left, section of main haulage drift. Fig. 2, at right, section of footwall haulage drift

roughly parallel to it for the length of the stoping area. Crosscuts were then driven, at about 400-ft. intervals, to the extraction drifts in the orebody, which were driven parallel to the strike of ore. The first extraction drift was driven on the footwall and other drifts were driven at intervals of 44 ft. or 60 ft., depending upon the width and dip of the orebody.

It was found desirable to advance small drifts in the orebody ahead of level development. This was because ore outlines that were projected from the known ore limits on the level to the stope-floor elevation did not prove satisfactory, owing to sharp changes in the dip of the footwall. These stope-floor drifts were driven near the center of the ore and parallel to its strike. Contacts were located by diamond drilling from stope-floor drifts at intervals of 80 ft., which corresponds to the center line of stope sections.

Longitudinal or extraction drifts were driven after stope-floor contacts had been determined. No. 1, or the first longitudinal drift, was driven about 10 ft. inside the orebody from the footwall. From this position the footwall chutes were driven to the stope floor at a point about 16 ft. from the footwall. From this position it will be possible to offset these chutes on each floor and keep them parallel to the footwall, which has a dip of about 65 deg.

The second longitudinal drift is located on 44-ft. centers from the footwall longitudinal drift. The number of longitudinal drifts varies with the width of the orebody. In widths of 70 ft. or less, one drift driven in the ore near the footwall was all that was necessary. In widths of 200 ft., four longitudinal drifts were driven. Chutes are located on opposite sides of these drifts, at intervals of 22 or 27½ ft. The necessary manways for stoping are driven with the chutes. Stope-fill raises are located near the center of the orebody from footwall to hanging wall, and are driven inside of the stope limits at the north pillar. With orebody width over 160 ft., a second fill raise is driven near the footwall.

The fill raise near the center of the stope is connected with the second or third longitudinal drift on the level above. This is done for a twofold purpose. *First:* As the stope on the level above advances, practically all of the ore goes to the chutes leading to the footwall longitudinal drift. This eliminates a certain amount of congestion under stoping areas, since ore is hauled in the first drift, and waste fill to the stopes on the level below is delivered to the stope-fill raises through the second or third drift. *Second:* Ventilation plans call for vertical as well as for horizontal air splits. Fresh air will enter stopes by way of the footwall longitudinal drift; used air from levels below will be delivered to the return air system through the second or third drift.

A small part of the waste filling required in the mining operations will come from underground waste development; rock sorted in the rock house, and sorted rock from the Creighton rock house and crushing plant, will be the main source of supply. The waste fill from these sources will be passed underground in either of two fill-raise systems which extend from the 2,800 level to surface. Each fill raise system is located centrally to a mining area.

Fig. 3—Section through No. 3 shaft

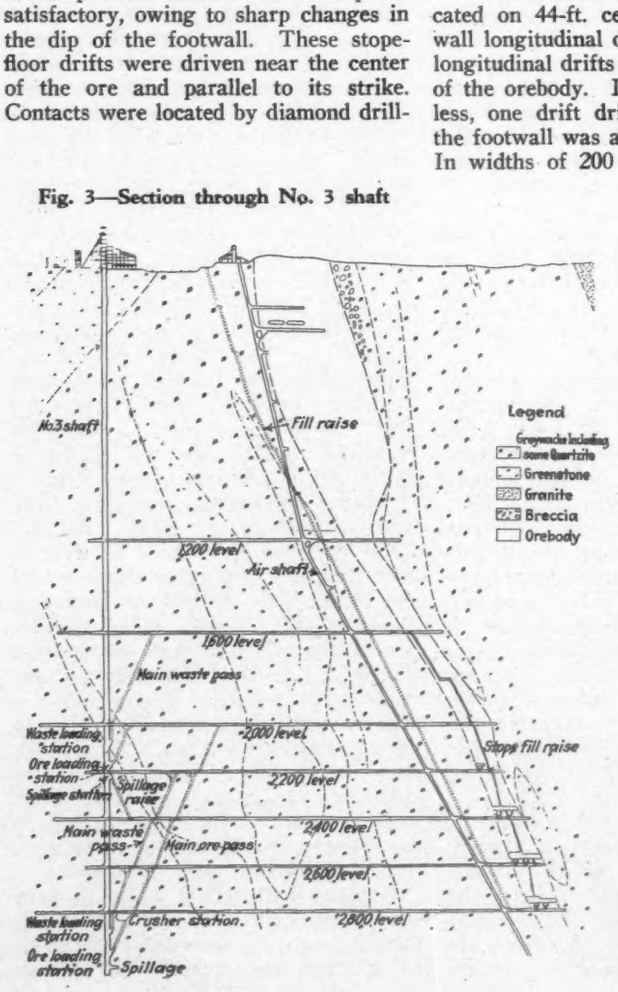
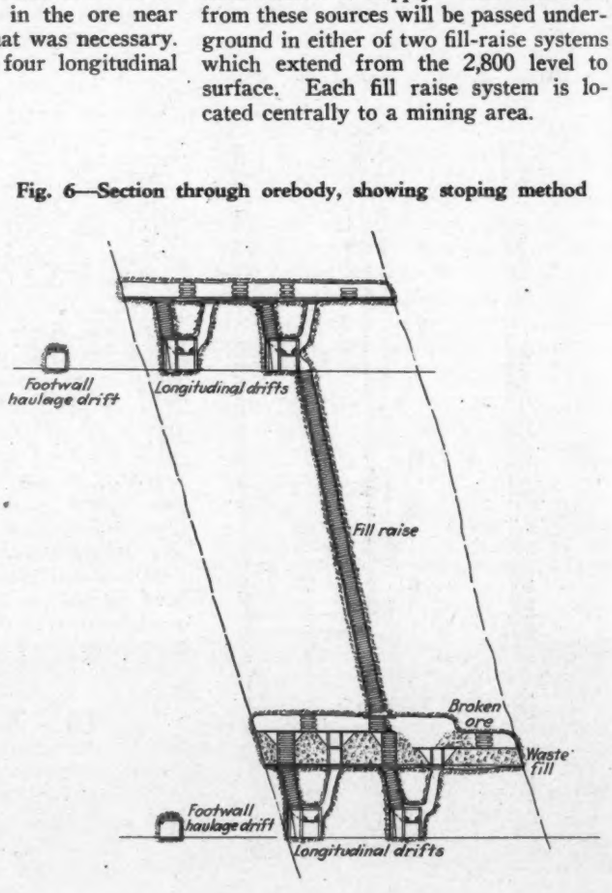


Fig. 6—Section through orebody, showing stoping method



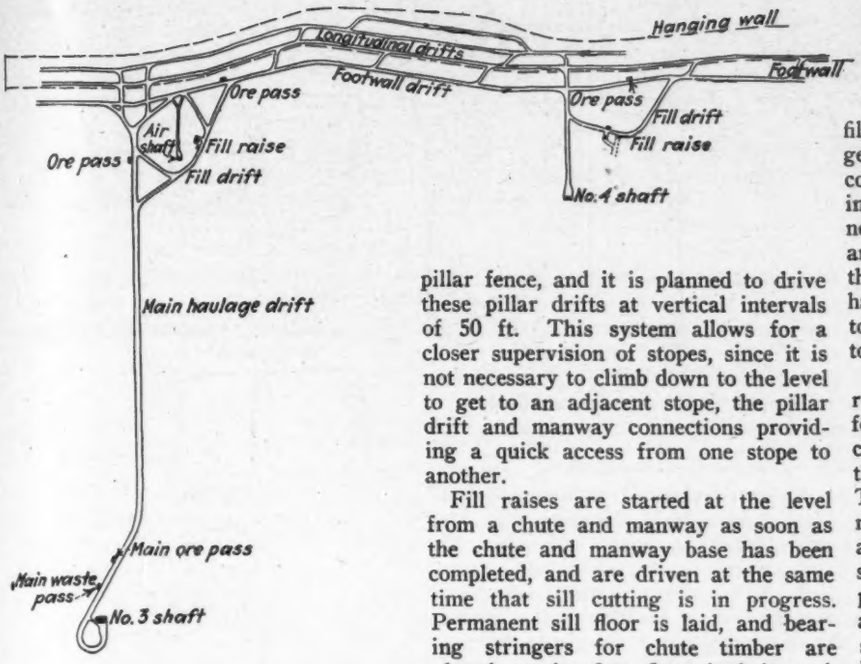


Fig. 4—Typical level plan

The orebody is laid out in 80-ft. sections beginning at the south end of the mine. Each section comprises a 45-ft. stope and a 35-ft. pillar, the stopes and pillars extending the full width of the orebody from footwall to hanging wall. Pillars and stopes are superimposed from level to level, and lie at right angles to the general strike of the orebody.

The general practice is to cut the first mining floor 30 ft. above the level. This distance is measured from the base of rail. The sill or first floor mining is started from the stope-floor drift after the chutes have been driven to the stope-floor elevation. A pilot drift, driven over the south line of chutes, is carried ahead of the main breast. All bench rounds are pointed to the pilot drift. This method allows for a maximum amount of ore to be blasted direct to chutes and makes it possible to keep the mucking floor close to face, as well as to carry permanent sill floor and grizzly stringers along with the sill cutting, so that when the first floor is completed to the hanging wall everything is in readiness for the regular cut-and-fill cycle.

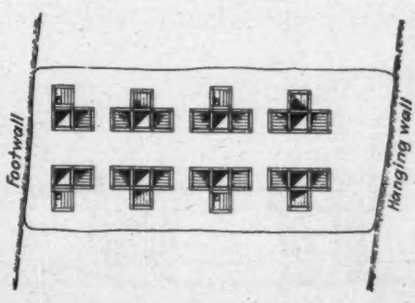
Chutes are spaced on 16½- or 27½-ft. centers from pillar to pillar, and on 22-ft. centers from footwall to hanging wall and starting with the footwall chute. (Fig. 5). A manway is driven with each of the two footwall chutes, and will be carried along with the offset chute, all repairs and inspection of footwall chutes being done from these manways. Two other manways are usually put up from the second longitudinal drift. Stope manways are driven in pairs on opposite sides of the stope and near the pillars. The stope-floor drift is connected to the manways by providing passageways behind the pillar fence, and it is planned to drive these pillar drifts at vertical intervals of 50 ft. This system allows for a closer supervision of stopes, since it is not necessary to climb down to the level to get to an adjacent stope, the pillar drift and manway connections providing a quick access from one stope to another.

Fill raises are started at the level from a chute and manway as soon as the chute and manway base has been completed, and are driven at the same time that sill cutting is in progress. Permanent sill floor is laid, and bearing stringers for chute timber are placed as the first floor is being advanced. After sill cutting has been completed to the hanging wall and the fill raise has been driven to the level above, the regular cycle of cut-and-fill operations is started.

After the second 7-ft. slice has been mined beyond the fill raise, the square-set chutes with wing extensions shown in Fig. 6 are placed on the chute-bearing stringers at regular square-set intervals, and a 7-ft. layer of waste fill is started. The chute timbering and waste filling are kept as close as possible to the mucking, so that the third slice may be started at the fill raise or at the footwall, as soon as the second cut has reached the hanging wall. Each subsequent floor is a repetition of this procedure.

The series of joints running horizontally from footwall to hanging wall and the specific gravity of the ore in the massive sulphide areas have necessitated a change, in some instances, from horizontal cut-and-fill to a modified system of square-set stoping (Fig. 9). The desire to eliminate all fire hazards, so far as possible, has led to a try-out of this method, which permits the removal of about half of the timber as waste filling advances. This system is being generally adopted in all stopes requiring continuous roof support. The ground in these areas is not heavy and does not cave, but small slabs a few feet in area and up to 8 in. thick drop out of the roof with but little warning. This has occurred in areas which were known to have been solid two hours previous to the fall of ground.

Fig. 5—Stope plan, showing arrangement of chutes and manways



The usual procedure in supporting the roofs in the cut-and-fill stopes is as follows: A line of bulkheads on 17-ft. centers is placed on the center line of the stope, beginning at the footwall. These bulkheads (cribs) are built of native pine timbers 8x10 in. x 7 ft. long, and are slabbed on the corners to withstand the blast. These cribs are put in place before the second cut is started, and on the waste fill before starting each succeeding slice. The 7-ft. slice is broken down on the bulkheads, and as the mucking advances they are raised up through the broken ore to the 14-ft. back. Between the bulkheads the roof is supported by lagging placed on 8x10-in. stringers which extend between the cribs. The square-set chutes are raised as uncovered, and bulkheads are extended from the chute timber to the roof. The sides of the square-set are left open for mucking until the next chute is uncovered, when the same procedure is followed. In bad areas in a stope, it is possible, with this method, to support the entire area. The bulkheads are removed as the waste filling is brought in, and are placed on top of waste fill in position for the next slice.

No. 3 shaft is the main hoisting and supply shaft. It extends from the surface to a depth of 3,045 ft. The shaft is 28 ft. 2 in. x 16 ft. outside of timber, with inside dimensions 26 ft. 6 in. x 14 ft. 4 in. It is timbered with 10x10-in. British Columbia fir, with concrete rings at intervals of 100 ft. extending the height of one set. The shaft stations are of reinforced concrete, with the concrete extending one set above and one set below each station.

Of the six compartments in the shaft two 14 ft. 4 in. x 6 ft. are for handling men and material, two are used for ore-hoisting, one 6x7½ ft. is a service compartment, and lastly there is a 7½x6-ft. pipeway and ladderway compartment in which a counterbalance on the service cage operates.

The system of ore and waste passes is shown in Fig. 3. Plans called for underground crushing before hoisting, and the crusher was installed below the 2,800 level, it being a 48x36-in. jaw crusher, set to a 6-in. opening. The crusher feeds into an ore-loading pocket having a capacity of 1,500 tons (Fig. 11). The ore from the levels between 2,800 and 2,000 is delivered to the

crusher through the system of ore passes previously mentioned. Development waste has been handled through waste passes to a loading pocket installed below the 2,800 level, but in the future this waste will be hauled to main waste raises, or dumped direct into stope fill raises. Waste from the lowest mining level will be hoisted to surface and delivered to the top of the main waste passes.

Stations were cut below the 2,000 level and temporary pockets installed at elevations which will correspond to permanent pocket locations for mining above the 2,000 level. Later, when ready to start mining operations in the 1,200 level area, it is planned to install a crusher on the 2,000 level, with a system of ore passes leading from the 1,200.

No. 3 shaft ore hoist, with a rope speed of 3,000 ft. per minute, is a Nordberg double-drum direct connected to a 3,200-h.p. d.c. motor at 600 volts, at a speed of 79 r.p.m. A 2,500-kw. Westinghouse flywheel motor-generator set with a 51-ton flywheel, driven by a 2,000-h.p., 2,300-volt, 3-phase, 4-pole wound-rotor induction motor, supplies power to the hoist. The drums are cylindrical, 12 ft. in diameter, with a 7-ft. spiral-grooved face, and will hold 3,300 ft. of 1¾-in. rope in two layers. The skips operate in balance and have a capacity of 130 cu.ft., or approximately 10 tons of ore.

Both men and material are handled by a hoist that is a duplicate of the one used for hoisting ore. Power for its operation consists of a motor-generator set of 1,300 hp. with an 11-ton flywheel operating a 1,000-h.p. d.c. motor at 600 volts and 40 r.p.m., direct-connected to the hoist. The hoist has a rope speed of 1,500 ft. per minute.

The service hoist is used for hoisting men and for miscellaneous work. It is a Wellman-Seaver-Morgan double-drum hoist, with a 10-ft. diameter, 5-ft. face drum. It is driven by a 500-h.p., 25-cycle motor, operating at 500 r.p.m., with single reduction gears to the hoist. The cage is a single unit with a counterbalance which operates in a part of the pipeway and ladderway compartment.

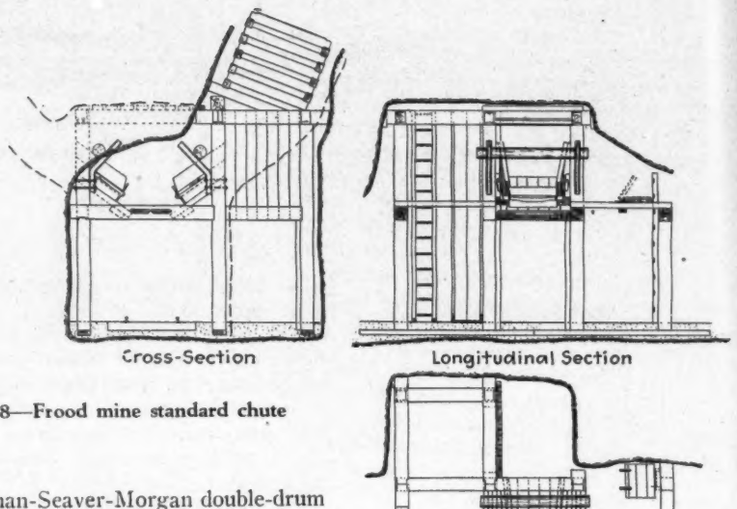


Fig. 8—Frood mine standard chute

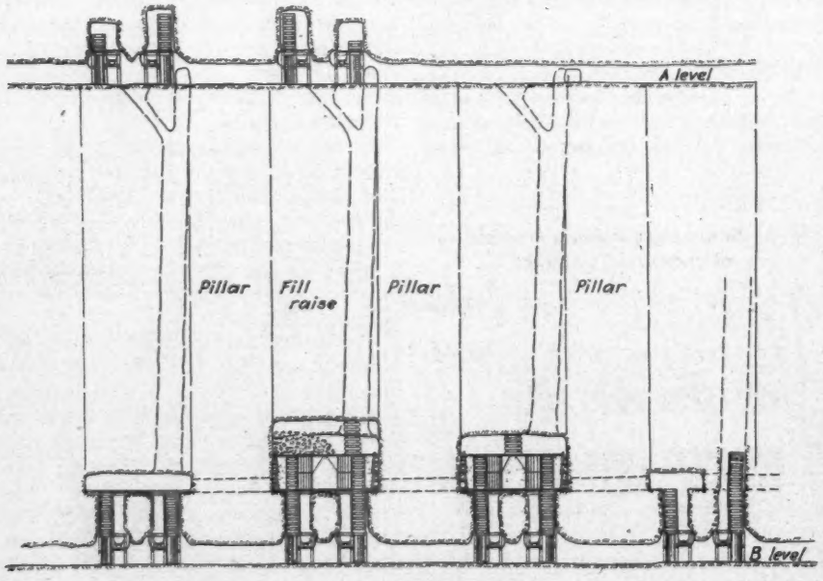
No. 4 shaft is about 2,000 ft. north of No. 3 shaft, the collar being about 500 ft. from the hanging wall of the orebody. It enters the orebody at 1,150 ft. and reaches the footwall 1,450 ft. from the collar. The total depth of the shaft is 3,345 ft. No change has been made from the original sinking equipment. A large part of the work which has been performed in the north end of the levels under development has been done from No. 4 shaft.

No. 1 shaft has been extended to the 2,800 level, and will be used as the intake air shaft for the mine. The original shaft timbers are being replaced with concrete from the 1,200 level to surface. From the 1,200 to the 2,800 level, 8-in. H-beams placed on 8-ft. centers with reinforced concrete to the face of the beam will be used for roof support. It is planned to install track and man cages in this shaft to serve in an emergency. The present hoisting equipment and especially designed cages will be held in readiness in the event of a fire in the main hoisting shafts.

All drifting and breast stoping are carried on with Leyner-type machines. Self-rotating stopers are used in chute and raise driving, and small pluggers in the stopes for blockholing. Portable slusher loaders carrying a double-drum hoist are used in some main headings when speed is essential, but have not given a lower cost than hand mucking. Hoe-type scrapers are used on the slusher loaders and have been useful for slushing in some stopes when chutes were spaced at a very wide interval. Material is hoisted into the stopes through an inclosed timber-slide built into the manways. Column-bar air hoists are used for this purpose and for hoisting material in raise driving.

Throughout the mine, 3-ft. gage track, with 40-lb. rail, is standard. Scoop cars of 18-cu.ft. capacity are used in driving stope-floor drifts and spreading waste fill in the stopes. These cars operate on an 18-in. gage track made up of 16-lb. rails in standard sections of 8-ft. lengths. The 2,400 and 2,800 levels are equipped with 8-ton trolley locomotives, and are the main haulage levels. The trolley extends only to the orebody from No. 3 shaft and through the length of the main footwall drift. Six-ton storage-battery locomotives are used on these levels to gather the ore from the stoping areas and deliver waste fill to the stope-fill raises. Six-ton storage-battery locomotives are also

Fig. 7—Longitudinal section through orebody, showing mining method



used for both ore and waste haulage on the 2,200 and 2,600 levels.

A system of ore-pass raises, near the orebody, leading from the 2,200 to the 2,400 level and from the 2,600 to the 2,800 level, provides for dumping the ore from the intermediate levels into the ore passes to be hauled to the shaft on the main haulage levels.

The 2,800 level is equipped with 105-cu.ft. tipple-type cars for ore haulage. These cars are dumped by single-car rotary tipples. Pneumatic car feeders of the pushing type handle the trains through the tipple by means of a duck-hook carriage under the track. The other levels are equipped with 52-cu.ft. Granby-type cars for both ore and waste haulage. Development work on levels not equipped with automatic dumps has been carried on with 27-cu.ft. cradle dump cars, but these cars, when worn out, will be replaced with Granby-type cars.

No. 1 shaft will serve as the fresh-air carrier to the underground levels, when completed. It will have an effective area of 120 sq.ft. from the 1,200 level to surface, and this section will be smooth-lined. The section below the 1,200 level will have an area of 140 sq.ft. The shaft will be fireproofed throughout, and the main fan, which will be reversible, will be placed on the surface in a fireproof housing. For safety, the emergency hoist housing and other buildings adjacent to the collar of No. 1 shaft will also be fireproofed.

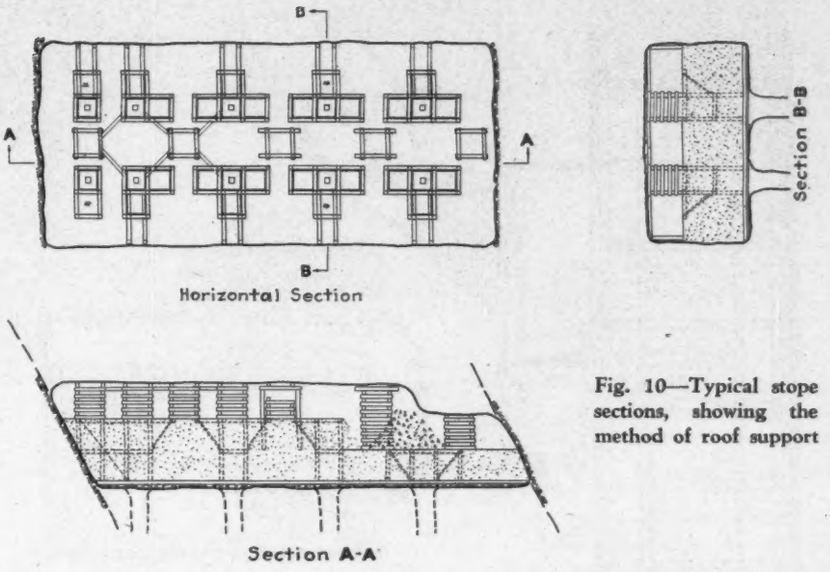


Fig. 10—Typical stope sections, showing the method of roof support

Air will be delivered from No. 1 air shaft on each of the mining levels to the stopes, through the main footwall drifts. These drifts have been fireproofed from the connection with No. 1 shaft through the crosscuts to the intersections with the first longitudinal drifts. The back-timbering method used (Fig. 2) consisted of setting 8-in. I-beams on blocks which were placed on 2-in. steel pins set into the walls near the roof. Then, 5-in. I-beams were placed on the 8-in. cross beams on 24-in. centers and blocked against the back. The 8-in. cross beams also serve to carry all pipe, light, and trolley lines.

Fresh air will enter the stopes by the footwall manways and chutes. If only one fill raise leads from a stope to the level above, the original raise cribbing is maintained in the raise. The cribbed compartment serves as an air passage from the stope to the level above while

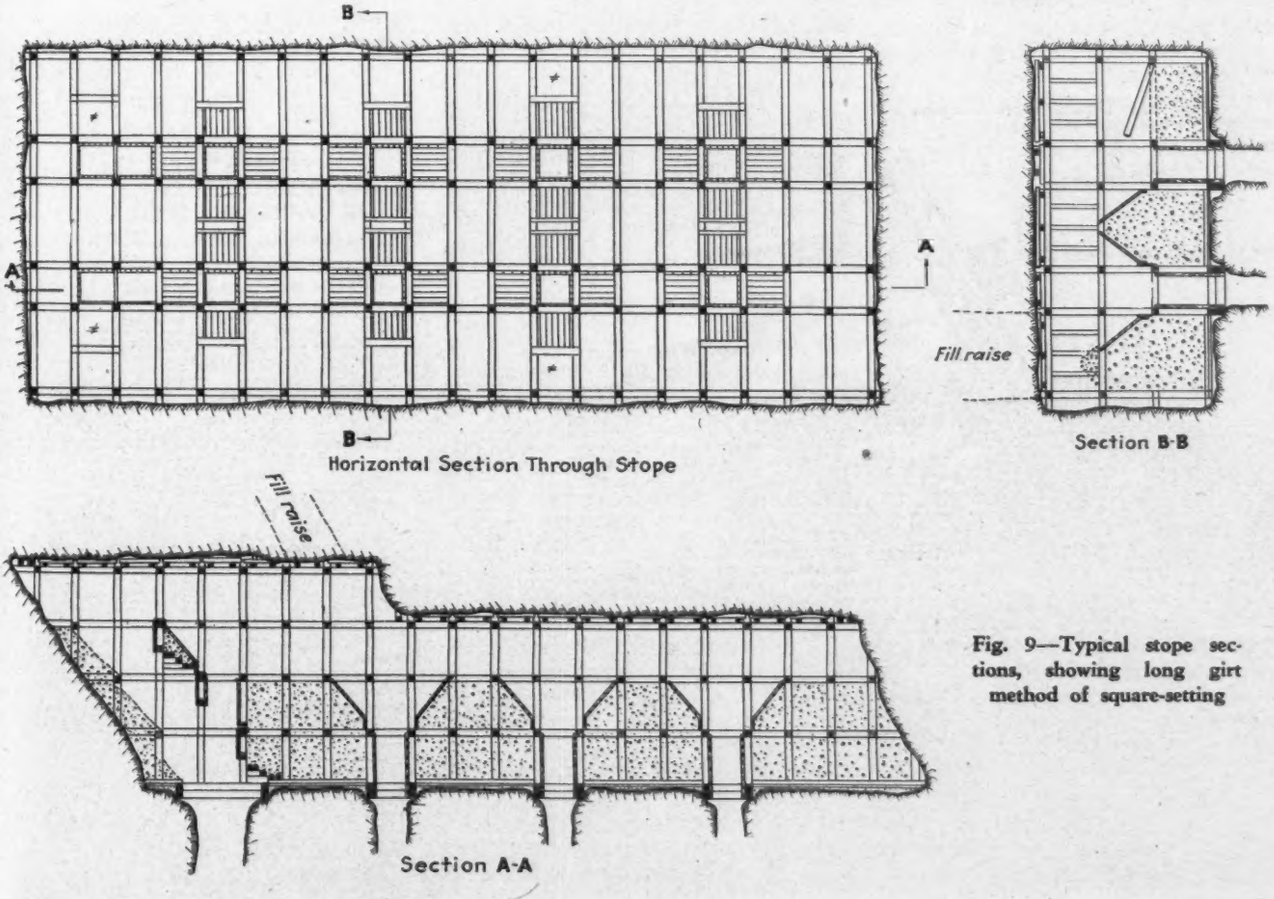


Fig. 9—Typical stope sections, showing long girt method of square-setting

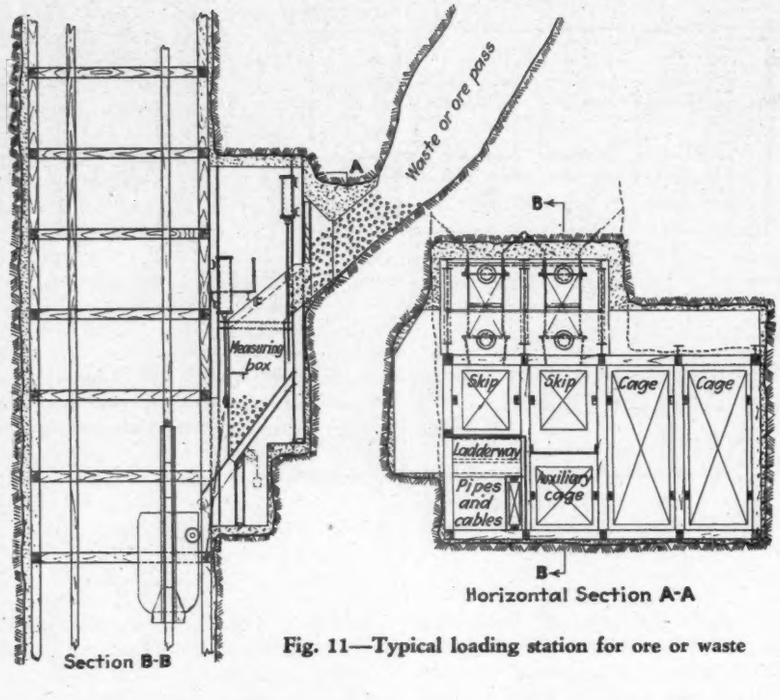
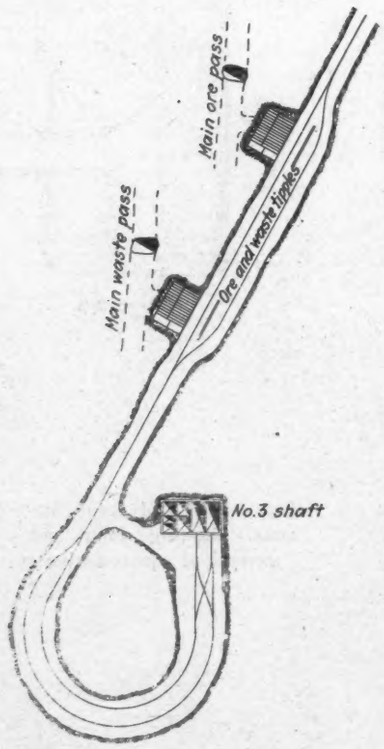


Fig. 11—Typical loading station for ore or waste

the chute side is being used in passing waste fill into the stope. Waste air will be bypassed to the main drift on the 2,000 level, whence it will be delivered to No. 4 shaft, which will serve as a return air shaft until a permanent return air raise can be driven from the 2,000 level to surface.

Approximately 100,000 gallons of water is pumped daily. The main pump stations are on the 1,200 and 2,800 levels at No. 3 shaft. Each station is equipped with two DeLaval multi-stage centrifugal pumping units, each unit consisting of two six-stage pumps mounted on the same bedplate. The capacity of each unit is 240 g.p.m. against a head of 1,625 ft. Power is supplied by a direct-connected 200-hp. motor, operating at 1,500 r.p.m. A 4½x 10-in. single-acting vertical triplex pump is also held in reserve at each pumping station.

Fig. 12—Typical station layout



Accident prevention is considered of first importance, as described in another article. A full-time safety engineer carries on the details of the work, assisted by a general safety committee which meets semi-monthly to receive and discuss accident reports, review practices and working conditions, and enact regulations to lessen their hazards. Semi-monthly meetings of shift bosses are held underground during the lunch hour, and a safety talk is given them by the safety engineer. Workmen's safety committees make an inspection of all working places every two weeks, reporting unsafe conditions to the safety engineer. Illuminated bulletin boards are maintained at all shaft stations. National Safety Council posters, home-made prints, reports of discipline cases, and shift bosses' accident-rate prints are displayed and changed weekly. Hard hats, gloves, and safety shoes are standard equipment. Goggles are furnished free of charge, and their use is enforced. A first-aid expert is on duty in the first-aid room at all times, and practically all bosses have received first-aid training.

The area covered by the Frood mine surface plant is approximately 3,300x 1,100 ft. Formerly, a considerable part of this area was swamp land, which has since been filled and leveled with rock from underground development work. No. 3 shaft is near the eastern margin of a swamp which lies between it and the ridge of gossan.

The arrangement of the Frood surface plant (Fig. 14) was made with reference to No. 3 shaft, through which all men and materials will be handled. The shaft headframe is built into the rock-house bins, and the collar house extends from the rock house to the compressor house, covering the lower part of the shaft headframe. On the south side of the collar house is the building housing the warehouse, blacksmith shop, and drill-sharpening shop; on the north side, in relatively the same position, is the building occupied by the machine and electrical shops. A mine-gage track extends from the warehouse, through the collar house, past the machine and electric shops, to the timber yard, where spurs turn off at intervals of 66 ft. and run between the timber piles. Spurs also run from this line into the warehouse, blacksmith shop, drill-sharpening shop, and machine and electric shops, as well as through the length of the carpenter and timber-framing shops.

Turnouts in the collar house extend to the man and material compartments of the shaft where a double crossover permits switching of trucks from one compartment track to the other. In addition to the mine-gage track, a standard-gage track extends from Copper Cliff to the mine. Branches from this line extend to the warehouse, under the rock-house bins, and into the timber yard. Another spur line, on which are located the two main fill raises, extends to No. 4 shaft.

The building which houses the three hoists operating in No. 3 shaft covers an area of about 20,000 sq.ft. In this building are also five Bellis & Morcom air-compressing units; a 750-hp. synchronous converter for supplying current to the standard-gage line to Copper Cliff; and a motor-generator set for

Fig. 13—Sections through air shaft, showing method of lining

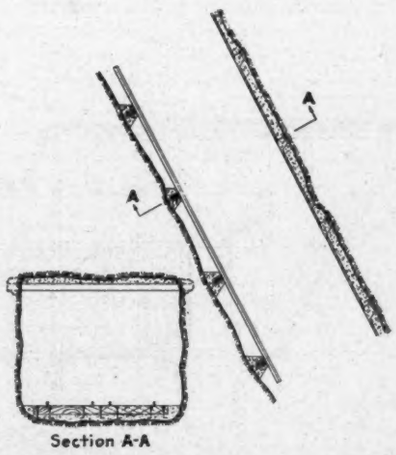
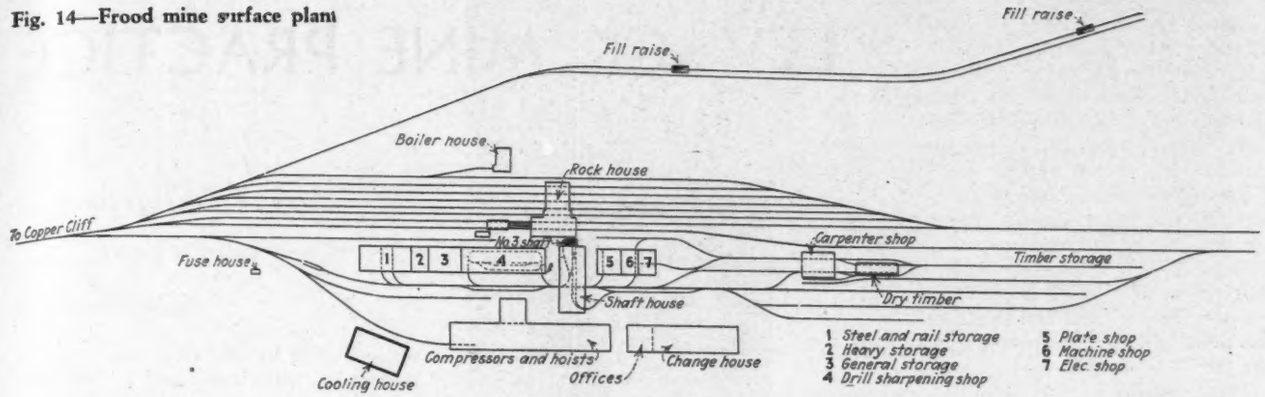


Fig. 14—Frood mine surface plant



supplying current to the motors operating oil accumulators for the No. 3 shaft-hoist brakes, and to the magnetic pulleys in the rock house. Each compressor unit consists of a two-stage vertical compressor with a capacity of 5,000 cu.ft. of free air per minute to 100-lb. pressure. Power is supplied to each unit by a direct-connected 1,050-hp. synchronous 2,300-volt, 25-cycle motor, operating at 214 r.p.m. The compressor plant has a total capacity of 25,000 cu.ft. per minute.

A single building houses the warehouse, blacksmith shop, and steel-sharpening shop. All material required for the operation of the mine is handled through the warehouse, where approximately three months' supply is kept on hand.

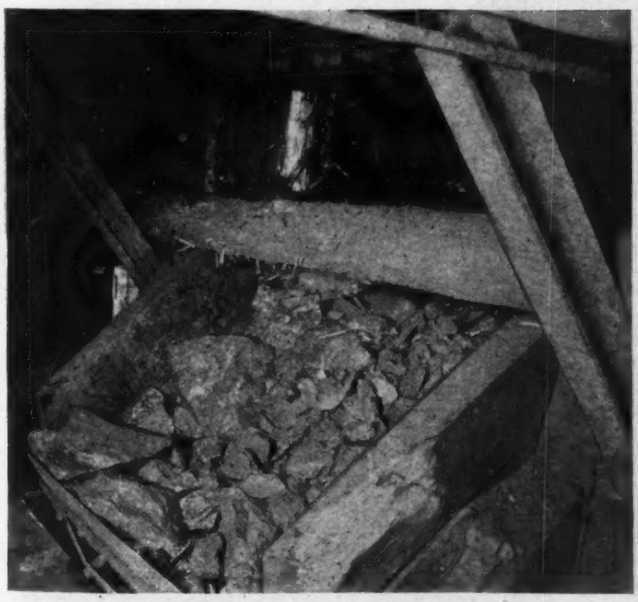
The blacksmith shop equipment consists of two forges and one steam hammer. Gads and scaling bars, as well as numerous other small articles required for the operation of the mine, are made and repaired here.

The steel-sharpening shop equipment consists of eight steel-sharpening machines arranged in pairs, each pair served by one oil furnace. Two oil furnaces are used for heat-treating and tempering the steel. The maximum capacity of the steel shop is 8,000 pieces daily, when operating on a two-shift basis, though the present requirements for the mine are about 5,500 pieces per day. One-inch hollow hexagonal steel of about 0.75 per cent carbon content is used.

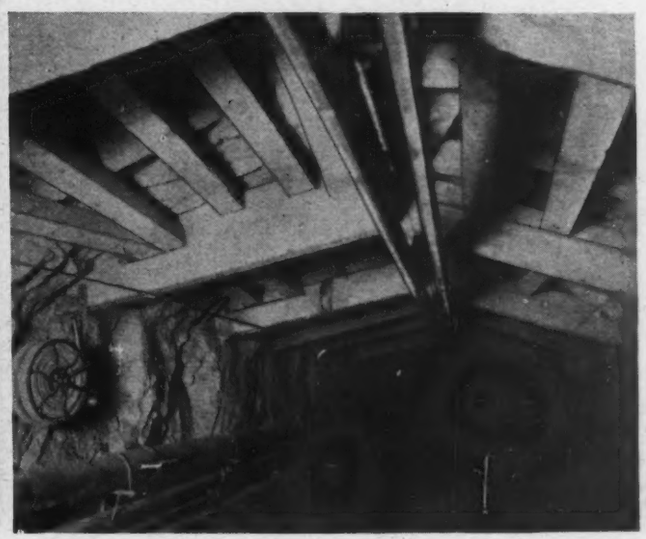
To the left, a view down into No. 3 shaft

Machine shop and electric shop occupy a building covering about 6,500 sq.ft. Machine-shop equipment consists of one 24-in. stroke shaper, one bolt-cutting machine, one pipe-cutting and pipe-threading machine, one hydraulic ram, one large lathe, one drill press, a motor-driven grinding machine, and a pushing and shearing machine, as well as a miscellany of riveting and welding equipment. Two forges are used for blacksmith work required in connection with machinery repairs. The electric shop contains all the necessary equipment for handling and repairing motors and welding light and trolley wire hangars, and other miscellaneous electrical equipment.

At present all framing of timber for the mine is done in the framing shop. Equipment consists of one framing machine, one gaining machine, one boring machine, one planer, two ripsaws, one bucking saw, and one bandsaw. Timber requirements for the mine are supplied from the timber yard, occupying an area



Left, a loading chute on the 2,400
Below, method of supporting the roof



of about 120,000 sq.ft. at the north end of the surface plant. About 3,000,000 b.ft. of timber are kept in stock. Each kind and size of timber is piled in its allotted space, so that no confusion results in handling the many different classes used in the mining operations.

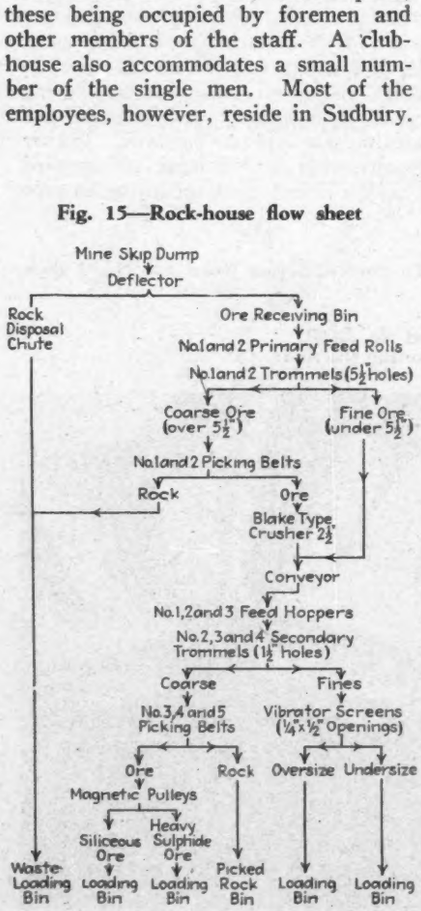
Steam for heating all surface buildings and hot water for the change room are supplied by two tubular coal-burning boilers, though a large tubular wood-burning boiler is being installed at present to utilize sawdust and shavings from the timber-framing shop and scrap timber from the mine.

Treatment of ore in the rock house involves crushing, coarse and fine screening, hand-picking waste, and magnetic separation of heavy sulphides high in pyrrhotite. Six products result: (1) fine ore under ¼ in., (2) fine ore from ¼ to 1½ in., (3) coarse sulphide ore, (4) coarse siliceous ore, (5) sorted waste rock, and (6) direct-hoisted waste.

The change house is close to the No. 3 shaft-collar house, and covers an area of approximately 12,000 sq.ft. It is equipped with steel lockers and shower space sufficient to accommodate 2,250 men. The lockers are connected with a forced hot air circulating and exhaust system, which insures efficient drying and airing of clothing. The mine, time, and survey offices are also here.

All main buildings of the mine surface plant are of steel and brick construction. Several dwelling houses were built near the mine surface plant, these being occupied by foremen and other members of the staff. A clubhouse also accommodates a small number of the single men. Most of the employees, however, reside in Sudbury.

Fig. 15—Rock-house flow sheet



LEVACK MINE PRACTICE

—A. L. Sharpe

Superintendent at Levack

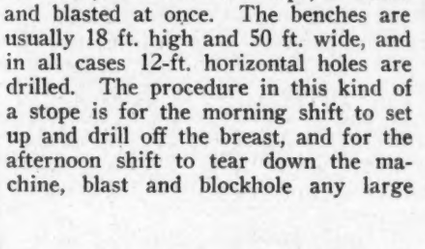
THE Levack mine has for some years been one of the principal producing properties of the Mond Nickel Company, shipping to the Coniston smelter. Here, the mining method employed is shrinkage stoping, using stopes 100 ft. wide, separated by pillars 40 ft. wide. In some of the stopes where the nature of the ground indicated possible trouble, a rib pillar 10 to 12 ft. wide has been left, but is cut off on the footwall and hanging wall as stoping progresses toward the levels above. In the stopes where the rib pillar has been used, scaling has been cut to a minimum and success has been such that no bad scaling of the back has occurred, so the rib-pillar method will be used entirely in the future.

In preparing a level for mining, a main or haulage drift is driven on the strike or long axis of the orebody, and from this drift two parallel drifts, 8x7 ft. in the clear and at 50-ft. centers, are driven under each stope and running from footwall to hanging wall. These are the mucking drifts, and from these crosscuts chutes are driven up at regular intervals at 16-ft. centers on alternate sides of the drifts, to the level of the stope floor, which is approximately 24 ft. above rail level. When the box-holes are up to the stope-floor level, section cutting is started. This consists of a slice 7 ft. high running from pillar to pillar and from footwall to hanging wall. As the stope-floor section progresses the chutes are funneled out so that the rim of one chute funneling touches the one following. In this way the entire stope floor can be cleared of ore when the final drawing of the broken ore occurs. When the stope-floor section is finished and the ground will permit, an 8-ft. section is cut up the footwall to the floor sill above and from this section all breasts are started. A rib pillar, left up the footwall at the center, is removed as the breasts are broken.

All stopes are entered by a small raise driven up from the floor or footwall sections, and in this raise are installed ladderway, pipe lines, and a chute for handling steel, timber, and miscellaneous material, equipped with a small bucket and hoisted and lowered by a Little Tugger hoist.

In stopes where no rib pillar is used, over half, or 50 ft. of the stope, is drilled and blasted at once. The benches are usually 18 ft. high and 50 ft. wide, and in all cases 12-ft. horizontal holes are drilled. The procedure in this kind of a stope is for the morning shift to set up and drill off the breast, and for the afternoon shift to tear down the machine, blast and blockhole any large

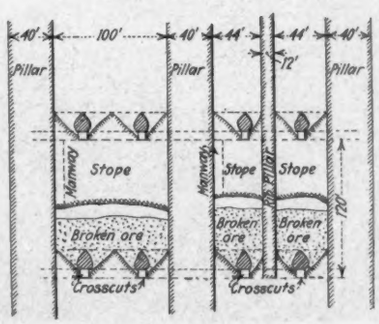
Section of Levack orebody

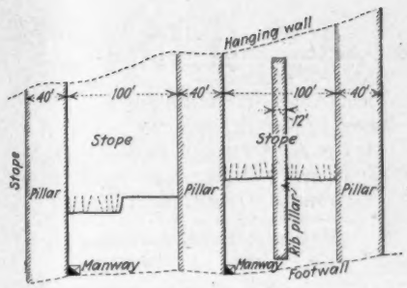


pieces, and then scale and prepare the other half of the stope for the following day shift.

In drilling, the two machines near the center of the stope drill their back holes slightly higher than the machines near the pillar; this gives a slight arch to the roof which seems to prevent the roof scaling badly. In stopes having a rib pillar, a separate equipment is used in each half of the stope. The procedure of drilling and blasting is the same.

Section across stope





Plan of Levack orebody

Supply station on 2,800 level of Frood mine, where material can be requisitioned for immediate use

In blasting, 40 per cent dynamite is used. Ordinary safety fuse, with No. 8 detonators, is cut and prepared in the fuse house on surface, no cutting of fuse or crimping detonators being allowed underground. All holes are tamped with clay made up into cartridges about the size of a stick of dynamite and wrapped with gum paper to distinguish the clay from the dynamite.

In stoping, four machines of the water Leyner type are set up, not at equal distances across the face but near either side, leaving the distance between the central two rows of holes slightly greater than near the sides. Each machine drills two rows of holes, one on each side of the bar; each row contains four 12-ft. holes. This work is done on contract, the company supplying all equipment, dynamite, and air.

The drifts are 8x8½ ft. and a crew consists of two machine men and one helper, with two men on the following shift to do the blasting for two crews. The men on the day shift set up, drill, and tear down the machines; the night shift crew does the blasting. A round consists of 24 holes using a square cut with 10-ft. holes in the cut and 9-ft. holes for the square-up. Rounds average slightly over 8 ft. Mucking is done on company time, and six men using a scraper machine clear up, tram (an average of 500 ft.), and dump the muck from two headings in eight hours.

So far, hand-tramming has been used entirely, but on the new level now being opened up motor haulage will be used. The cars are the end-dumping type, with trucks bolted solidly to the body and the wheels running on roller bearings. They have a capacity of 33 cu.ft., or approximately two tons of ore. The track gage is 18 in., and 25-lb. steel rails are used throughout the mine. Granby-type cars and 24-in. gage will be used in the future.

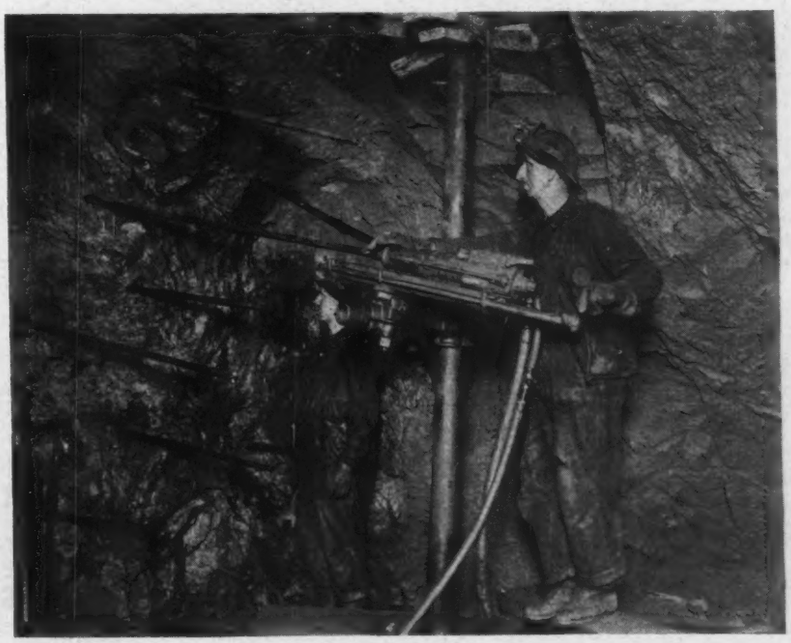
The ore drawn from the chutes is trammed to a grizzly placed near the shaft and above a shaft ore pocket connecting the various levels and leading to the main skip-loading station on the twelfth level. Grizzlies are made of 85-lb. steel rails with the rails spaced 15 in. in the clear, thus making an opening 15 in. square. All oversize is broken with sledges, the rock and ore being full of small cracks or fractures.

Where stoping is being carried on, about 40 per cent of the material broken has to be drawn off after each blast to get room for drilling the next breast. In stopes where no rib pillar is used, the machine men are drilling on the left-hand side of the stope while the muckers are drawing off the surplus muck on the right-hand side. Only sufficient muck is drawn to allow the machines to be set up properly. When the footwall flattens, causing an undue amount of stope mucking, branch raises or sublevel drifts, from which chutes are driven, are used to handle the material that will not run to the chutes in the main-line crosscuts.

Hoisting is carried on in two 6-ton skips running in balance. They are operated by a Nordberg hoist with a drum 10 ft. in diameter and a gear connected to a 650-hp. a.c. motor. The hoist is equipped with Lilly controllers, which cut off the power in case of overspeeding when coming to the dump, or overwinding, and automatically set the brakes.

In 1929, a new fireproof substation was erected at Levack mine, entirely separate from the other buildings. It contains one 1,500-kva. bank of transformers, water-cooled, 44,000 to 550 volts, and one 750-kva. bank of transformers 44,000 to 550 volts, self-cooled, fed through a G.A.-3 oil circuit breaker. Outgoing feeder circuits to the various parts of the plant are grouped in a separate switch room.

Starting another hole at Creighton



HOISTING AND COMPRESSOR EQUIPMENT AT FROOD

David Butchart

Master Mechanic of Mines

NO. 3 Shaft, Frood mine, is served by three hoists. The ore hoist and the cage hoist were built by Nordberg and are similar in design, but have different hoisting speeds. They are first-motion, double-drum, electric hoists driven by d.c. motors with Ward Leonard control. The electrical equipment, supplied by Canadian Westinghouse, consists of:

For the Ore Hoist—A 3,200-hp. 600-volt, 79-r.p.m. d.c. motor. The current is supplied by a flywheel motor-generator set consisting of two 1,250-kw., 600-volt, 720/610-r.p.m., d.c. generators; a 2,000-hp., 2,200-volt, three-phase, 25-cycle, wound-rotor, induction motor; a 42-kw., 250-volt exciter; and a 50-ton steel-plate flywheel.

For the Cage Hoist—A 1,000-hp., 600-volt, 40-r.p.m., d.c. motor. The current is supplied by a flywheel motor-generator set consisting of a 1,250-kw., 600-volt, 720/610-r.p.m., d.c. generator; a 1,300-kw., 2,200-volt, three-phase, 25-cycle, wound-rotor induction motor; a 42-kw., 250-volt exciter; and a 10½-ton steel-plate flywheel. Both hoist motors are controlled by the Ward Leonard system. The control is a full magnetic type using current limiting, accelerating, decelerating, and protective relays.

The mechanical parts of the hoist include:

Drums—Cylindrical, cast-steel drums with plate-steel shells, 12 ft. diameter by 7 ft. face. Capacity of each drum 3,300 ft. of 1¾-in. diameter rope in two complete layers.

Brakes—Parallel-motion, gravity-release, post-type brakes, with basswood blocks, hydraulically operated.

Clutch—Cast-steel, radial-tooth crown gear, positive-type clutch, hydraulically operated. The movement of one tooth of the clutch corresponds to 6 in. of rope travel.

Drum Shaft—Nickel steel, 21½ in. diameter.

Safety Devices—Model "D" Lilly controllers are used in addition to the current-limiting, accelerating, decelerating, and protective relays supplied with the electrical equipment, and in addition to the usual safety devices.

The third hoist, or service-cage hoist, was built by Wellman-Seaver-Morgan and is a double-drum electric hoist, driven through one gear reduction by a 500-hp., a.c. motor with a speed of 500 r.p.m. It is designed to handle a maximum load of 19,000 lb. at a rope speed of 1,500 ft. per minute. This hoist operates a light cage with a counterbalance.

The working conditions of the hoists may be summarized as follows:

Shaft—Vertical.

Fleet Angle—1 deg. 25 min.

Sheaves—12 ft. diameter.

Maximum Hoisting Speed—Ore hoist, 3,000 ft. per minute; cage hoist, 1,500 ft. per minute. Hoisting in balance.

Maximum Loads on Ropes

	Pounds		
Ore Hoist:	1,200 Level	2,000 Level	2,800 Level
Weight of empty skip	15,000	15,000	15,000
Weight of ore	24,100	19,100	14,800
Weight of 1¾-in. diameter rope	7,000	12,000	16,000
Total rope pull	46,100	46,100	46,100

Cage Hoist:

	Pounds
Weight of empty cage	16,000
Weight of 60 men@160 lb.	9,600
Weight of 1¾-in. diameter rope	16,000
Total rope pull	41,600

Factors of safety of rope:

Ore-hoist ropes: 6.4

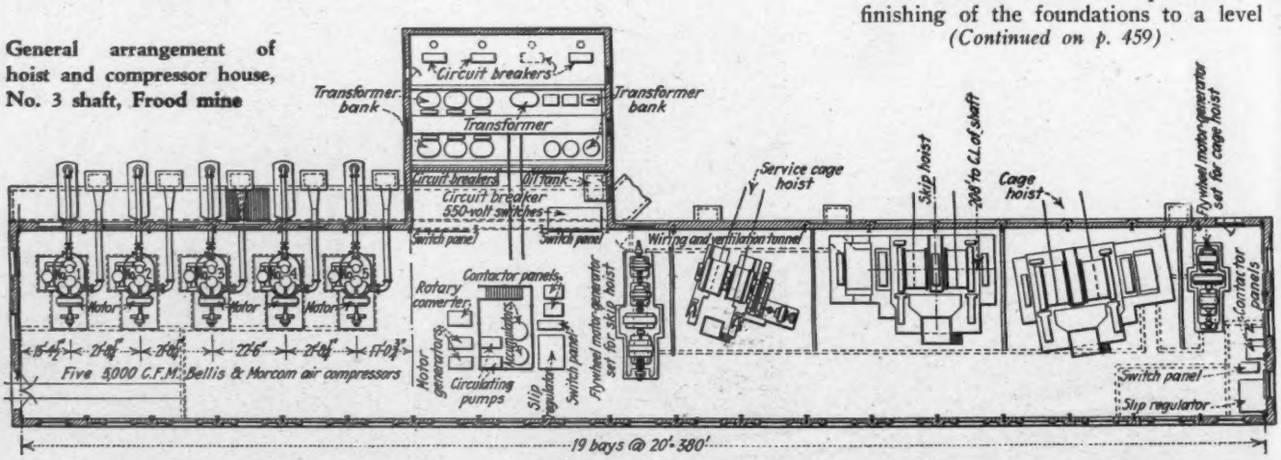
Cage-hoist ropes: 7.1.

Compressor Plant

The compressed-air plant consists of five units in the western end of the power house. The compressors, built by Bellis & Morcom, are vertical, two-stage machines, with 42x25-in. cylinders and 19-in. stroke, capable of compressing 5,000 cu.ft. of free air per minute to a final pressure of 100-lb. gage at 1,000 ft. altitude. Each is direct driven by a 1,050-hp., 214-r.p.m. Canadian General Electric synchronous motor. All parts are force-lubricated at 10- to 20-lb. pressure by a simple pump without loose valves or packing. The used oil drains back into a sump in the crankpit, to be strained and used again. Both inlet and discharge valves are Rogler-Hoërbiger patent type. Intercooling is very efficient, the high-pressure cylinder discharging at approximately 198 deg. F. above atmosphere. Four compressors handle the present maximum load with one set to unload for variations in pressure.

Particular attention was paid to the finishing of the foundations to a level

(Continued on p. 459)



General arrangement of hoist and compressor house, No. 3 shaft, Frood mine

THREE YEARS OF CONSTRUCTION

James H. Brace

Vice-President, Fraser-Brace Engineering Company, Limited

IT IS the purpose of this article to describe the actual building of the works involved in the developments undertaken by the International Nickel Company of Canada, Limited, and other allied interests, and carried out by Fraser-Brace Engineering Company, Limited. The construction company, as the Fraser-Brace company will be called throughout this article, simply acted as agents for the owners and was charged with the duty of looking after the owners' interests in every way possible.

The first step in the expansion program consisted in extending the existing hydro-electric development. Preliminary operations for the power house at Big Eddy, on the Spanish River, were begun in the fall of 1927, and the power house was built in 1928. On Feb. 27, 1928, work was started on the surface works for the Frood mine. On July 9, 1928, work was started on the new smelter and carried on continuously until its approaching completion during the present year. Repairs to the storage dams near Bisco were completed during the autumn of 1928. In 1929, the refinery and acid plant were started for allied interests; also the additions to the nickel refinery at Port Colborne, and the new headworks and other additions at Levack. The sintering plant at Coniston and repairs to the power plant at Wabageshik were also undertaken. In 1930, the fine-crusher and screening plant at Creighton were built.

The magnitude of the work is best illustrated by the following quantities of work involved:

Excavation, cu.yd.....	552,000
Concrete masonry, cu.yd.	170,300
Brick masonry, M.....	9,924
Tile masonry, M.....	1,547
Firebrick, M.....	5,358
Structural steel, tons....	51,129
Area of roofs of buildings, sq.ft.	1,610,000

During the latter part of 1928 and the early part of 1929, the owners indicated that they desired all works completed so that refined nickel and copper could be produced by the new plants not later than Aug. 1, 1930. All of these works were carried on under cost-plus fixed-fee agreements. As each new job came up a fee was agreed on, and this plan has resulted in wonderful co-operation

between the builders and owners, so that a great amount of work has been done in a very short time.

Carloads of machinery and equipment installed totaled 1,300. Detail quantities for each individual plant are shown in the table on p. 458.

Although the general plans of the development were well worked out in the minds of the executives of the nickel company before any work was done, few detail plans had been made and usually these were not completed until after construction was under way.

Based on the completion dates, careful and detailed schedules were prepared for each of the different jobs and for the different units of each job. The supply of labor, particularly in some of the skilled trades, especially bricklayers, was limited, and therefore much thought was given to arrange the order of the work, so that operations requiring particular classes of labor could be carried on at seasons of the year when such men would ordinarily be unemployed. From the fact that work involving total payrolls of approximately $7,200,000 was carried out without any strike or other evidence of dissatisfaction on the part of the workmen, as well as that there was never any serious shortage of labor, it appears that reasonable success was attained. I also believe that the company's motives were understood by the workers as a whole, and I wish to take this opportunity to express my appreciation of their intelligent and faithful efforts.

Construction on most of the work was started at about the same time as the preparation of detail plans, so it was necessary to co-operate closely with the designing engineers as well as anticipate the time of construction in making practicable schedules. Efforts were also made to schedule the work so that the superstructures of the principal buildings could be housed in during the warmer months and the interior work and installation of machinery could be carried on during the cold months. This was not always possible, so considerable portions of the brick and tile walls and the wood or gypsum roofs, with their waterproof coverings, as well as structural steel, had to be erected during the winter. Buildings, such as the dust chamber, storage bins, crushing and screening plant, and reverberatory flues, on which the plans were well advanced or which did not require much complicated steelwork, were started first, so that the masonry gangs could get to work early in the season. These schedules were designed also to serve as a guide in fixing the dates of delivery of equipment and in placing sub-contracts.

The owners, builders, and contractors for the structural steel and other large items all co-operated in carrying out the schedules. Furthermore, the new structures usually were linked with those in operation, so it was necessary that work be carried on without interrupting production. This also called for much forethought and some forbearance to avoid friction, but there were no interruptions of serious nature.

In carrying out the work the construction company acted as the owner's agents in providing an organization and supervising the work. With the refinery and acid plants, it also assisted largely in the buying of materials of construction and minor items of equipment. It also designed the power plant at Big Eddy and the alterations at Wabageshik and Bisco, and, as well, did most of the detail work on the design of the structure and electrical equipment of the refinery.

Contracts were let to the bridge companies for the fabrication and erection of the structural steel and to specialists for the roof coverings, brickwork in stacks, and for items of equipment. Most of the rest of the work was done by the construction company.

All purchasing for the work for International Nickel was done under the supervision of the company's general purchasing agent, W. T. Waterbury, with headquarters at Copper Cliff. Owing to the able and sympathetic

efforts of Mr. Waterbury and to the fact that he was located on the work, this arrangement was entirely satisfactory. In the other works the larger items were purchased by the owners' purchasing departments at their home offices, and the minor items, particularly those that could best be handled locally, were purchased by the office manager of the construction company.

Under practically all of the different contracts, such as for steel and equipment, the owner agreed to supply facilities, as tracks, for handling materials and often to supply or handle the materials themselves, and to furnish facilities such as water, compressed air, and electric current. These obligations usually devolved on the construction company. Speaking generally, and without reference to this particular work, I have found that few recognize how much effort and expense are involved in the aggregate of such obligations, but it is evident that one of the most important functions of the general construction company is to obtain close co-operation among the owners, contractors, manufacturers of equipment, and material men. Such co-operation was gladly given on this job.

The construction operations were under my general supervision. G. C. Clarke had charge of the design of permanent works done by the construction company, and N. J. Kayser had charge of the refinery during its earlier stages, and later assisted in the general supervision of the refinery and acid plant. Gordon Stephen designed most of the construction plants, prepared the detail schedules and assisted in securing delivery of material and equipment. J. J. McCarthy was general superintendent of all of the work for the Nickel company; E. M. Kayser was in charge of the work at the refinery; and Eric Smith at the acid plant.

In general, the organization of each job consisted of a superintendent; assistant superintendent or general foreman, depending on the size; a master mechanic, a chief electrician, and on the larger jobs during the installation period, an assisant superintendent in charge of installation. The office forces on each job were in charge of an office manager, or chief clerk, and consisted of cost engineer, timekeepers, and other necessary staff. The superintendent generally had a young civil engineer assistant, and at the refinery and acid plant, as well as some of the outlying works for the nickel company, forces of field engineers for the layout work were also required.

The work was carried out under the general direction of Robert C. Stanley, president of the company, and with close personal supervision on the ground by J. L. Agnew, vice-president. This direct contact between the chief executives and the work resulted in rapid progress. L. M. Sheridan, chief engineer, and his staff were always on hand to give practical help and accomplished wonders in producing the complicated plans as they were needed.

In general, the plan of procedure consisted in providing a central mixing plant for concrete and its distribution by railway tracks, special hopper cars, and gasoline locomotives. Most of the coarse aggregate for the concrete was brought from a pit 30 miles from Sudbury. The gravel was quite uniform in composition but carried an excess of sand, so crushed stone had to be added. For a time Frood development rock was used, but as the work approached the orebody, the rock carried enough sulphides to make it unsuitable for use in concrete, and a quarry near Copper Cliff was then opened. Practically all of the other building materials were produced at distant points. The structural steel was all erected by the use of locomotive cranes, and nearly always it was possible to construct standard-gage tracks so that the steel could be taken directly from the railroad cars and put into place by long-boom locomotive cranes.

Smelting and Concentrating Plant at Copper Cliff

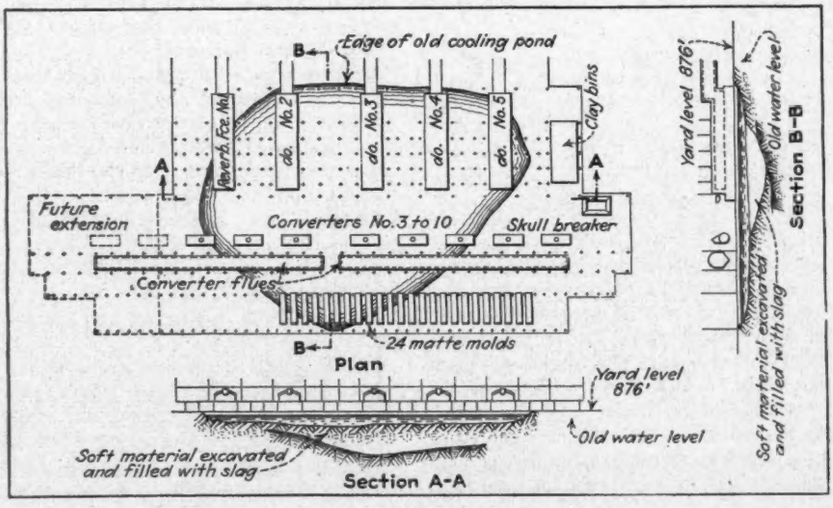
Work was started on this plant July 9, 1928. The site chosen was between the former blast-furnace and converter plants on the west and the reverberatory and roasting plants on the east. All of the above plants were being operated to their utmost capacity, and it was a first consideration to interfere as little as possible with production.

Fortunately no important buildings were on the proposed site. It was, however, crossed by the reverberatory slag tracks, operated by an overhead electric trolley system, but they were not far from the location for the slag tracks for the new reverberatories. One of the first operations undertaken was to do the necessary rock excavation and shift the tracks into approximately their final position. The tracks were in use continuously, however, while they were being shifted.

A part of the site was occupied by a cooling pond (see accompanying sketch), which provided the only serious foundation problem encountered throughout the work. After draining the pond, the slime bottom, three or four feet thick, was removed by a dragline bucket operated on a cable. Small crosses on the plan show the locations of the column foundations. The heaviest loads come on the row of columns on Section A-A, and this sketch, together with the cross-section, shows the relation of the rock to these footings. The clay overlying the rock was in layers of varying thickness and some of it very soft. It was proposed to fill the pond up to yard level with molten slag. Those responsible for the work feared, however, that the clay beneath might be squeezed out, allowing the entire building to slide. Therefore a trench was dug down to a hard foundation and filled with slag. This trench was under the most heavily loaded columns, and confined the clay and increased its resistance to sliding. Later the entire area of the cooling pond was filled up to the yard level with molten slag. This required about 166,000 tons. As soon as this area was cool enough, the concrete walls around the bases of the reverberatory furnaces were placed and filled with slag. These walls were built with a 16-in. lining of 8-in. hollow tile to prevent burning the concrete. It was necessary to pour the slag in layers about 18 in. thick and allow considerable time for cooling; otherwise, the walls would have been badly cracked.

The question of shrinkage or settlement due to cooling caused concern, as no data were available as to how long it would take this mass of slag to cool or what the contraction would be. Observations showed that settlement practically ceased after about three months, or before it was necessary to set the column bases.

Arrangement of smelter over old cooling pond



Necessary temporary buildings consisted principally of the carpenter shop, machine shop, blacksmith shop, and mixer plant. The mixer plant was located near the smelter stack adjacent to the high-level track leading to the old reverberatory ore bins. Gravel, stone, and cement were handled by a clamshell bucket operated by a stiff-leg derrick. For the reverberatory group, the concrete went directly into hopper cars, and was discharged therefrom directly through gate hoppers into concrete buggies for placing in the forms. In all of the mill buildings on the opposite side of the track, concrete was discharged into a tower bucket and hoisted to an elevation that made it possible to run into hopper cars on the high-level tracks. These cars were then taken by gasoline locomotives throughout the different buildings, the tracks thus required also serving for handling the steel framework, machinery, brick, lumber, and concrete forms.

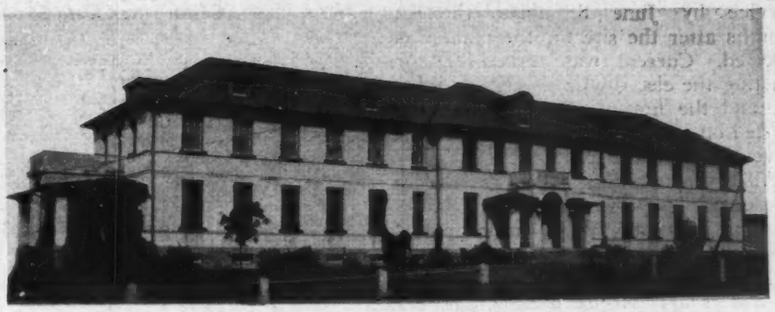
The foundations were not mass work, but consisted of walls, piers, and floors. The average concrete poured was 200 cu.yd. per day, and some of it was placed in temperatures as low as 32 deg. below zero. As part of these foundations were on the slag fill, it was necessary, however, to take measures to keep the concrete cool rather than warm.

Most of the steelwork was supplied and erected by the Dominion Bridge Company, whose readiness to meet schedules was a great factor in the progress of the work. The structural steel in the entire group amounts to approximately 35,000 tons, and it was soon recognized that this could not all be placed in time to house in the entire plant before the winter of 1929-30. As the smelter could operate on raw ore, this part of the plant was rushed and a maximum of 250 bricklayers was employed during December, 1929. By April, 1930, the concentrator group was housed in. Some of the brick and tile walls were laid in the open at 25 deg. below zero. The walls were allowed to freeze, but showed no ill effects in the spring.

The traveling cranes were placed in position as soon as progress on the steel framework would allow, and they became immediately available for placing machinery. Some of the heavy equipment, as the converters and a part of the rod mills, was placed by locomotive cranes in advance.

Installation, except for the concentration group, was practically completed during the winter of 1929-30, and matte was produced from the first reverberatory furnace on June 11, 1930. The first concentrate came from the mill on Aug. 19, 1930. One of the longest operations connected with the installation was lining the 30 roasting furnaces.

The old works had required little water, so a new water-supply system was installed to supply process water from Kelley Lake. A pump house was established on the lake shore, and two pipe lines, one 16-in. and one 12-in., were laid to a distance of 12,000 ft., through rock and muskeg. Most of the trenching in muskeg was done in winter when the material would stand up. The storage pond is divided into two parts, one for storage of Kelley Lake water and the other for return water from the concentrator tailing. The combined capacity of the ponds is about 2,500,000 cu.ft.



Hospital at Copper Cliff

In all of the work above outlined, J. J. McCarthy was general superintendent; S. E. Holmes, superintendent; George Bullock, in charge of machinery erection; William Rowe, master mechanic; and L. J. McNally in charge of all office work, not only in the smelter group but on all of the work for the Nickel company. All electrical work was done by the company's own forces, under W. E. Gillespie.

Copper Refinery of Ontario Refining Company

The site of the copper refinery was selected on April 25, 1929, and work at once started on a level area approximately 2,200x800 ft. The topography was quite irregular, and the soil largely unsuitable for building foundations. Though the plant was arranged so that most of the buildings came on hard ground, and grading would be a minimum, it was necessary to excavate more than 200,000 cu.yd.

Building of the tanks, 1,216 in number, was, of course, a key operation. It was decided to build them of precast concrete sections, the casting being done while the building was in course of erection. The tanks were designed to be erected in groups, some of the walls being in common, but the 1,216 tanks required 8,384 precast pieces. The casting yard was adjacent to the central mixer plant, all within reach of a locomotive crane which placed the concrete in the forms and handled forms and finished slabs. Great care had to be exercised in placing the reinforcement to keep the steel from the surface of the concrete; otherwise short circuits would occur in operation. Casting was carried on in the open air until Dec. 10. Steam pipes were placed under the forms and the slabs covered with tarpaulin after pouring. Few were damaged by frost.

The concrete was composed of ¾-in. crushed granite, rock-crusher dust, and cement, and produced an ideal mix. An accelerator was added to the mix, and the slabs could be taken to the storage yard in from 24 to 36 hours. The tankhouse service cranes were used for erecting the tanks. Joints between slabs were grouted with cement and sand mortar. Practically no leaks were found in the lining.

Though the steel framework, walls and roofs were constructed during the middle of last winter, the work proceeded practically without interruption, including pouring the gypsum roofs; and the installation of the furnaces and boilers was begun before the buildings were completely housed in.

The water supply was obtained by building a pump house at Kelley Lake with a 12-in. pipe line 3,000 ft. long to the plant. In addition to the usual water lines required, an activated sludge sewage disposal plant was built.

Among the most important auxiliary works were the cooling pond and the railroad connecting this plant with the tracks of the Nickel company. The cooling pond covers an area of 350x314 ft. It was located on low ground covered with loose decayed vegetable matter. As this could not be readily stripped off in the winter, the area was surrounded with a row of sheeting driven about 6 ft. into the ground and extending above the level of the proposed water surface in the pond. Earth was then filled against the sheeting on both sides to make an enbankment 7 ft. wide at the top and with a slope of 2 to 1 on the inside and 1½ to 1 on the outside. The inner slope was riprapped with broken rock and the bottom covered with a layer of clean gravel to prevent the soft material from roiling the water. Although much of the material placed in the bank was frozen, no serious leaks have occurred.

The railway connecting the tracks of the Nickel company with the yards of the refinery crosses both the C.P.R. tracks and the main highway from Sudbury to the west by overhead bridges. It is about 2,480 ft. long and almost entirely built on muskeg. It was thought that the muskeg would not support a fill of the height necessary to carry the tracks over the crossings, so a trestle on piles of creosoted timber was built.

The first anode furnace was put int

service by June 8, about thirteen months after the site for the plant was selected. Current was turned on for starting the electrolytic process on June 30, and the first wirebar furnace was started on Aug. 1. The buildings themselves cover twelve acres.

All gypsum roofs were placed by Canada Gypsum & Alabastine, Limited. The construction company carried out all installation of equipment, both electrical and mechanical, with the exception of the boilers and coal-preparation unit. As practically all the workmen lived in Sudbury, the C.P.R. ran out a special train morning and night for their accommodation. The men were charged for the cost of this service.

N. J. Kayser, assisted by Eric Smith, supervised the operations. On the completion of the work at Port Colborne, E. M. Kayser took over the field supervision. P. C. Kirkpatrick was field engineer, R. L. Haycock had charge of the mechanical installation, and George Boissonneault of the electrical work.

Construction Data Showing Extent of Building Operations

Place	Excavation, Cu.Yd.	Concrete, Cu.Yd.	Structural Steel, Tons	Tile, M.	Red Brick, M.	Firebrick, M.	Roof Area, Sq.Ft.
Smelter.....	164,600	61,000	35,100	1,250	2,690	4,344	557,000
Refinery.....	305,000	40,000	8,000	200	2,250	750	625,000
Port Colborne	30,000	20,000	2,500	....	1,310	100	175,000
Frood.....	13,172	16,387	2,365	33	1,600	....	105,000
Acid plant...	12,500	4,447	760	46	570	121	70,000
Levack.....	7,426	5,078	814	15	241	....	20,000
Coniston....	7,200	6,800	920	3	758	43	38,000
Creighton...	200	563	227	....	65	....	4,000
Turbine.....	8,388	12,117	443	....	440	....	16,000
Bisco.....	....	2,653	.....	....	....	....	.....
Wabageshik.	4,093	1,244	.....	....	....	....	.....
Totals..	552,579	170,289	51,129	1,547	9,924	5,358	1,610,000

Addition to Plant at Port Colborne

Construction operations on the addition to the plant at Port Colborne were started Jan. 21, 1929, with the intention of having the first of the three electric units in operation by July 15, 1930. The work consisted of an addition to the electrolytic plant of 468 tanks, which were housed in a new building; an extension to No. 4 building with the installation of three refinery furnaces; and an extension to No. 1 building, with the installation of converters, holding furnace, and other equipment. The area covered by this new construction was 175,000 sq.ft.

The site of the electrolytic plant was approximately 700x150 ft., entirely inclosed on two sides and at one end. A layer of peat, from 2 to 15 ft. thick, had to be removed for the foundation. Back fill was made from granulated slag, thoroughly wetted and tamped. Although floors had to be laid on this fill immediately after it was placed, practically no settlement occurred.

Probably the most interesting feature was the construction of the concrete plating tanks cast singly in place. The aggregate consisted of sand and ⅜-in. traprock. The mix was rich in cement and as dry as was possible to handle in the forms. As the thin tank walls were heavily reinforced, great care was necessary in depositing the concrete to avoid a honeycomb structure. A bituminous lining was placed by means of forms inside the concrete.

The first unit of the addition was ready for operation July 15; the second, Aug. 1; and the third, Aug. 15, 1930. E. M. Kayser was superintendent, William Muir, assistant superintendent, and George Bulloch in charge of mechanical installation.

At the Frood mine the surface plant consists of a steel headframe 175 ft. high, together with a collar and rock house, a hoist and compressor house, a change house, and the necessary shops and stores. The combined area of these buildings is 105,000 sq.ft. They have a steel framework and the walls are of brick or tile. Construction was started on Feb. 27, 1928, and completed Feb. 28, 1929. Among the principal items of equipment installed were three high-speed mine hoists and five compressors.

A temporary wooden headframe and hoist house had been erected before the permanent works were started, and it was necessary to erect the steel headframe over the wooden one without interrupting hoisting. The corner columns carrying the new headframe were at wider centers than the old and were erected, along with the back legs and oins and all work above the old, and riveted solid. The timbers of the old headframe carrying the sheaves were then carried on the new steelwork, and one at a time, working downwards to the collar, the old intermediate columns were taken out and replaced by the new steel columns. Then the cross members carrying the guides were replaced by new members and the guides bolted thereto. The last operation was the taking out, one each day, of the old bins and the placing of the new cages. Meanwhile, the new cables had been put in place, and, except for the period of attaching to the new skips, work underground was carried on without let-up or accident. J. J. McCarthy was general superintendent; S. H. Holmes and later W. S. Muir were superintendents; and Mr. Haycock was in charge of mechanical installation.

Canadian Industries' Acid Plant

The project of providing an acid plant for Canadian Industries, Limited, required buildings for such a plant, a niter-cake plant, a works office, and sulphate storage. The site was an old slag dump, which made an excellent foundation but offered difficulties in the way of excavation. In this plant the buildings are generally of structural steel on concrete foundations with brick and tile walls and wood roofs. They were built mostly during the coldest part of the year, but otherwise construction presented no unusual difficulties. Work was started on Sept. 23, 1929, and completed on Aug. 31, 1930. Both the acid and niter-cake plants were brought into production by the end of June, 1930. A. T. Eric Smith was superintendent and also took general charge of the field engineering and installation, J. E. Thompson acting as assistant superintendent.

At Levack, Coniston, and Creighton

Construction and installation work at Levack mine consisted of an additional hoist house, a new steel headframe, and a rock house, equipment of the last-named including crushers, screens, and magnetic separators. Several additions were also made to the minor buildings. Thirteen additional cottages, a dormitory, and an extension to the schoolhouse were built in the village near by, and a water supply was provided for the townsite. The only special feature in connection with this work was that the headframe had to be installed while hoisting was going on and the hoist changed over and operated on a new headframe without interrupting the work. Work was started on May 7, 1929, and completed by Aug. 15, 1930. W. S. Muir was superintendent and R. L. Haycock had charge of mechanical installation.

At Coniston a new six-unit sintering plant was built, additional ore bins were provided, and an addition was made to the matte-casting shed. A new stack 175 ft. high and 14 ft. inside diameter was built in connection with these additions, the brickwork for which was done by the Canadian Kellogg Company. This work had to be rushed, and the only difficulty was in securing delivery of material and equipment at the times required. The work was started on July 9, 1929, and completed on Jan. 1, 1930. R. L. Smiley was superintendent, and Charles S. Bennett was field engineer.

An additional fine-crushing plant and storage bins were built in connection with the surface works for the Creighton mine. Fine crushers, magnetic separators, and sorting tables were installed. This work was started on April 15, 1930, and completed on July 15.

Hydro-electric Developments

To increase the amount of power available for the production of nickel during the World War, a large storage dam was commenced by the construction company in the summer of 1918 at the Big Eddy power site to regulate the flow of the Spanish River. This dam has a maximum height of 156 ft. and contains 82,600 cu.yd. of concrete. When the

dam was built, provision was made to use it as part of a future hydro-electric development by providing suitable intake works and penstock thimbles. Plans for additional power development were prepared during 1927 and 1928. Some preliminary work was done during 1927 and actual construction was commenced in the spring of 1928.

The Big Eddy dam will still be used for storage purposes, the head varying from 101 to 72 ft. It is expected that the river below the dam will be regulated to a minimum flow of 1,800 cu.ft. per second. To utilize the water under such a varying head most efficiently it was necessary to install somewhat greater generator and turbine capacity than would have been necessary had the head been more constant. The transformer capacity, however, was not increased. An 11-ft. 3-in. diameter butterfly valve, hydraulically operated, is located in each penstock immediately above the turbine.

The power house is laid out so that the generators, switchboard, transformers, and high-tension switching are all on the same floor level, although separated by suitable walls and barriers. The main floor of the generator room and the generators are supported by two rows of concrete arches running lengthways of the power house. Each arch spans a unit and thus has the advantage of carrying all the weight of the generators and floor system directly to the main dividing walls between the hydraulic units. This also has the effect of creating a roomy and airy basement.

At High Falls, a half a mile below the Big Eddy site, an outside switching station was built for interconnecting the two plants. Work commenced March 1, 1928, and the first unit started to deliver power Jan. 15, 1929. All three units were placed in service on March 4, 1929. M. J. Green was superintendent and P. C. Kirkpatrick, field engineer.

During the season of 1928 it was found that the lumbermen's dams at Biscotasing that controlled the level of Ramsay Lake were in an unsafe condition. This lake has been used for many years for storage, both for lumbering operations and power purposes. There are two outlets, each blocked by a rock-filled timber-crib dam. It was decided to replace one of these structures by a new concrete dam and to strengthen the other by additional rock fill. The only difficulty involved in this work was that of transportation, as the railway station was about 7 miles away, there were no roads, and it was necessary to use scows and motor boats for both men and materials. Gravel for concrete was brought by water from a pond 2 miles up the lake. The work was started on Aug. 15, 1928, and completed on Oct. 31, 1928. J. E. Thompson was in charge.

The concrete dams at Wabageshik were built many years ago and had deteriorated owing to the use of improper gravel, so that extensive repairs were necessary. The highest part of the structure consisted of the stop-log section. From the toe of the piers, a new concrete apron was built downstream, and was extended upstream to inclose the base of the piers. The vertical surfaces of the piers were then carefully chipped and covered with a coating of gunite. Drain tubes were inserted to draw off the water which was seeping through, and reinforcing mesh was then placed over the surfaces and held in place by dowels. Forms were then built around the piers, and a layer of concrete averaging about 6 in. thick was poured all around them. On the bulkhead section of the dam, a clay embankment was built against the downstream face to prevent further weathering of the concrete.

Owing to an accident, caused probably by a log getting inside the runners, one of the water wheels at this point was wrecked and had to be replaced by a new one. This plant is 5 miles from the railroad and considerable difficulty was encountered in bringing in the new water wheel and generator. A special steel truck was built for this purpose, hauled by a caterpillar tractor. R. L. Smiley was superintendent, and Charles S. Bennett, field engineer on this work.

Inco's Administrative Organization

THE International Nickel Company of Canada, Limited, is the parent and holding company conducting the operations described in these pages. Charles Hayden is chairman of the board; Robert C. Stanley, president; John L. Agnew, vice-president; John F. Thompson, assistant to the president; and James L. Ashley, secretary and treasurer. The directors number twenty-five, of whom fourteen reside in the United States, six in England and Scotland, and five in Canada. The company maintains a general office at Copper Cliff, Ont., and a Toronto office, at 80 King St., West, Toronto 2, Ont.

International Nickel of Canada owns outright its two principal subsidiaries, The Mond Nickel Company, Limited, whose office is at Imperial Chemical House, Millbank, London, S.W. 1; and The International Nickel Company, Incorporated, whose executive office is at 67 Wall St., New York. The Mond company conducts all the company's business in Europe, and is represented on the "Inco of Canada" board by D. Owen Evans as delegate director. "Inco Inc.," as it is called for short, owns, controls, and operates all of the properties of the company located in the United States. There are several minor subsidiary companies, such as those organized for supplying power to the company's Ontario works.

Inco of Canada owns 40 per cent of the Ontario Refining Company, Limited, with a copper refinery at Copper Cliff, and has a long-term contract with Canadian Industries, Limited, whose sulphuric acid plant is at Copper Cliff. This utilizes smelter gases, and sodium sulphate from a natural deposit of this salt in Saskatchewan leased to Inco of Canada, and whose development has been contracted to the Horseshoe Lake Mining Company, Limited.

Levack Mine

Hoisting and Compressor Equipment at Frood

(*Continued from p. 454*)

surface, using steel straight-edges which had been set absolutely level. After the concrete had set, the top of the foundation was dressed down to a level surface. The bedplate, the underside of which is planed to a true surface, was then placed on the foundation, and all high points of the foundation were marked; these were then rubbed down to give a perfect seat for the bedplate.

Air control is by automatic inlet valve, which shuts off the supply of air from the compressor when the intended working pressure is exceeded by 3 to 5 per cent, and reopens again when the pressure becomes normal. To overcome surge in the intake pipe, a space was left between two of the connection flanges, close to the compressors. The 24-in. outside diameter intake pipes connect with screened intake houses supported on concrete foundations on the north side of the building. The high-pressure cylinders discharge through 16-in. outside diameter pipe to the air receivers outside the building, in line with each compressor.

The 6-ft. diameter x 18-ft. long receivers discharge into the 18-in. air main through a 45-deg. lateral, delivering in the direction of the flow. The air main parallels the side of the power house and is housed in a concrete service tunnel, running underneath the air receivers. This tunnel carries the air main and other service facilities to the shaft and surface buildings and is of ample size for the proper inspection and repair of the service lines. Heat from the air main aids in heating the power house in the winter time.

FEATURES OF DESIGN OF MILL AND SMELTER

—*L. M. Sheridan*

Chief Engineer

DURING the last three years The International Nickel Company of Canada, Limited, has been engaged in a construction program of considerable magnitude, embracing additions to the Port Colborne refinery, the underground development and surface plant of Frood mine, the construction of a new smelting plant at Copper Cliff, additions and improvements to the Coniston smelter, and a new surface plant at Levack. The smelter and concentrator have been put in operation. Additional construction is now involved in transferring part of the Port Colborne operations to Copper Cliff, the part to be moved consisting of the process for separating the copper and nickel before the electrolytic refining operations take place. This article deals with some of the engineering problems involved in the design of the smelter and concentrator at Copper Cliff, a complete description of those units being given elsewhere in this issue.

The plant was designed by the staff of the Nickel company at Copper Cliff. All structural and mechanical design was under my supervision, and a general flow sheet and plan submitted by A. G. MacGregor, consulting engineer, were, in the main, followed. The entire erection was done by contract. Foundations, brickwork, lumber, piping, and most of the machinery were built or installed by the general contractors, the Fraser-Brace Engineering Company, of Montreal. The structural steelwork was erected by the Dominion Bridge Company, the blast piping and gas main to the Canadian Industries plant, by the Horton Steel Company. A number of other contractors installed individual equipment of various kinds.

All erection work was handled with smoothness and dispatch. The general contractors performed the work under the most difficult winter weather conditions, without delay in brick and concrete construction, and with the most harmonious relations to the other contractors and to the company's engineering staff. The erection of the structural steel by the Dominion Bridge Company was rapid and ahead of schedule at all times.

The plant is designed to crush, concentrate, and smelt approximately 8,000 tons of ore per day. Fig. 1 and the flow sheet on page 474 give an outline of the flow of material and the processes involved. Essentially, the plant consists of receiving bins and trackage, crushing and screening units, conveying systems, a concentrator in which selective flotation is practiced; and a smelter consisting of mechanical roasters, reverberatory furnaces, and converters, with the attendant coal-pulverizing plant, flue system, stack, water systems, and other auxiliary units.

The magnitude of the work is indicated by the following figures:

Tons of structural steel used	35,000
Brick in buildings, flues, and furnaces	7,034,000
Hollow tile (interlocking in buildings and flues)	1,250,000
Concrete in foundations and floors, cu.yd.	61,000
Combined ground area of all structures, sq.ft.	510,000
Combined floor area of all structures, sq.ft.	1,000,000
Tons of brick in smelter stack exclusive of foundations	15,000

The roasters are superimposed on the reverberatory furnace plant, which, in turn, has a floor elevation of 12 ft. above the converter floor. This makes necessary a rather high furnace building, it being 183 ft. from the yard level to highest roof elevation. The main smelter stack is the largest in the British Empire, being 512 ft. from the base to the top, or 554 ft. above the converter building floor. It has an inside diameter of 45 ft. at the top.

Most of the building foundations are carried down to bedrock, the only exception being part of the smelter building, which is built over an old cooling pond. The foundations for the stack are on solid rock, and the stack was built near the face of a rock ledge having a slope of approximately 20 per cent. To prevent possible slippage, due to seams in the rock, the stack-foundation site was diamond-drilled to a depth of 60 ft. and the cores were examined for seams and faults.

Owing to the heavy loads on the reverberatory-roaster building columns, in some cases as high as 1,400,000 lb. per column, and to the fact that the columns were close to the sides of the reverberatories, a difficult problem was presented. Experience has shown that reverberatory furnaces will spread, owing to heat expansion and to the impregnation of the base with matte. Over a period of years this spread may amount to several feet and in my experience the building columns are invariably pushed out of plumb. As a result of the heavy superimposed loads from the roasters, this condition might endanger the structure; therefore the following extraordinary precautions were taken to guard against this happening (Fig. 2):

(a) The building foundations were separated from the reverberatory-furnace foundations, for a depth of 6 ft., by expansion joints about 2 ft. wide at the column bases. Then the resulting holes or spaces were filled with "Insulex," a very porous gypsum which can be easily crushed under pressure. The top surface of the Insulex was protected by a light concrete slab.

(b) All foundations between furnaces were made in the form of long piers and heavily reinforced with longitudinal grillages to take end thrust, each pier taking two or more column bases.

(c) The building columns were heavily braced laterally, so that even if pushed out of plumb the bracing will take care of the heavy lateral thrust resulting therefrom.

In the structural steel design the specifications of the American Bridge Company were adopted, with some modifications, using 16,000 lb. net tensile stresses per square inch and 19,000—$100\,\frac{L}{R}$ for compression on main members. A wind load of 30 lb. per square foot and a snow load of 40 lb. per square foot were assumed. No main members were made less than $\frac{1}{4}$ in. thick, so as to allow for corrosion from the gases resulting from operations. All members were chosen with the idea of preventing the accumulation of moisture or corrosive dust on ledges of the steel work. The foregoing precautions made necessary a somewhat heavier steel construction than is met with in ordinary building construction.

Roofs on practically all structures are of slow-burning wood construction, consisting of 2x4s placed on edge. In buildings where furnaces are installed, all wood was impregnated with a zinc chloride solution under pressure, which completely penetrated the wood and made it fire resistant to the extent

that it will not sustain combustion. Brick roaster flues have an air space between the brick roof arches and the corrugated iron roof. The concentrator roof is of 2-in. matched boards with a half-inch insulation of wood fiber board, overlain with tar paper and finished with a slate-surfaced asbestos felt. Flat roofs are covered with Barrett Specification Roofing; all sloping roofs are covered with roll slate-covered asphalt roofing.

The experience of this company with corrugated-iron sheathing has not been satisfactory, because, first, it requires frequent painting to prevent corrosion, with a consequent heavy cost of upkeep; and, second, the insulating qualities are not sufficient to meet the low winter temperatures prevailing at Copper Cliff. For these reasons a fireproof wall was sought which would meet the requirements, and interlocking tile walls were chosen for practically all structures. They are, in the main, 8 in. thick and non-bearing. The tile chosen has a vitreous burn, making it nonporous, to prevent disintegration by frost. The lower eight feet of the walls was always made of brick to prevent damage to the tile by steel bars and heavy tools. Where blasting is likely to occur, such as at the steel ore bins, the tile walls are protected by heavy plank sheathing.

Doors and windows are of wood, no steel sash being used, because of possible corrosion by smelter gases. The doors are heavily ironed with T-irons.

In the smelter building elevated floors are made of $\frac{3}{8}$-in. checkered plate. Ground floors are made of concrete. In the concentrator and screening and crusher buildings, reinforced concrete floors are used, with a few isolated wood walk-ways and floors; conveyor-ways have wood floors. Effort has been made in all buildings to provide fire-resistant structures, so wood is used sparingly.

Since the ore is handled entirely by conveyors from the time it leaves the receiving bins until it reaches the roasting furnaces in the smelter, a great many of them are necessary, and they form an important link in the process. In the smelter conveying system are 47 belt conveyors, using a total of 24,000 ft. of rubber-covered conveyor belt. In addition, several drag-chain and screw conveyors of various sizes are used. The maximum length of any inclined conveyor is 514 ft., with a rise of 98 ft. and a maximum slope of 17 deg.

All cold material is handled on belt conveyors ranging in width from 24 to a maximum of 48 in. All troughing and return idlers are Timken roller equipped, and made by the Link-Belt

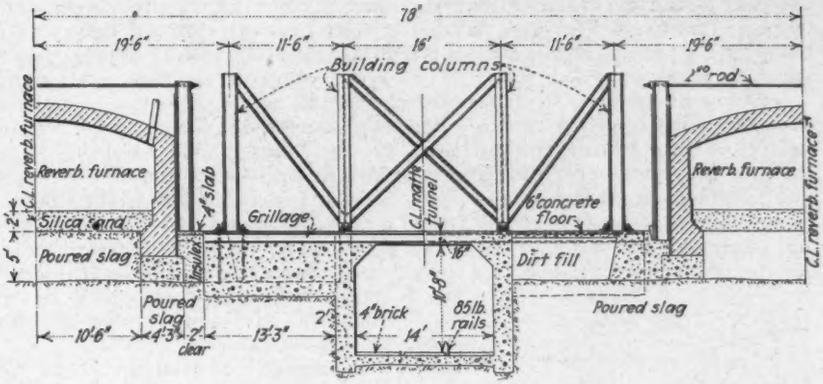


Fig. 2—Sections through column foundations

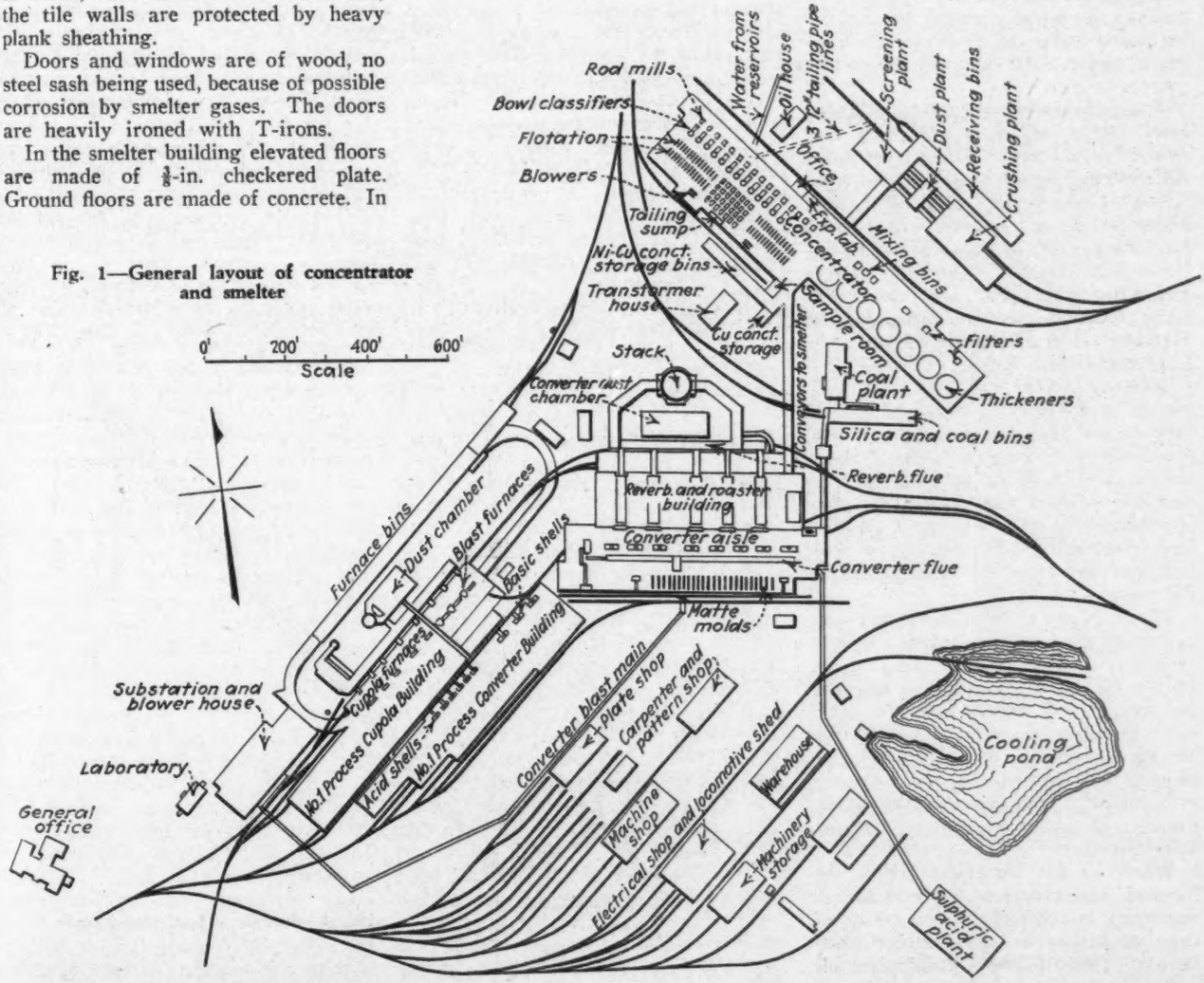


Fig. 1—General layout of concentrator and smelter

Company of Canada, Limited. Conveyor trippers (made by Stephens-Adamson Company) with slat-type snub pulleys are of the motor-propelled type.

Some novel features have been introduced in the conveyor system. For instance, in the transfer of discharge from the conveyors under the receiving bins to either one of two parallel belts at right angles to the line of flow, only the head and tail pulleys are made movable, with troughing idlers attached

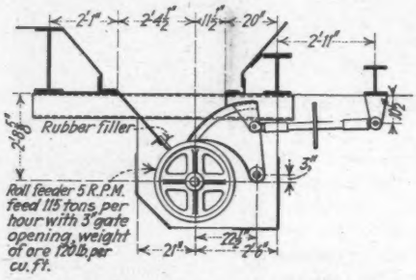


Fig. 3—Typical cross-section, showing roll feeder and gate at secondary screens

to spacing rods and a sufficient counterweight to keep the belt tight in all positions. The head pulley is moved forward by a "nigger head" on the end of the head-pulley shaft. In this manner, a conveyor 340 ft. long can be easily and quickly moved forward or backward under the power of the conveyor motor. All take-ups are of the counterweighted type.

The drives in general are from lagged head pulleys, and there are a few tandem drives on some of the longer belts. All snub pulleys are of the slatted type. Conveyor speeds are, in general, kept under 300 ft. per minute. The drives for all conveyors are through totally inclosed gear reducers of the herringbone and worm-gear types. Gear and worm speed reducers were furnished by the Hamilton Gear Company, by the Falk Corporation, and others.

Material is fed onto the belt conveyors from receiving bins and mixing bins, by belt feeders driven by variable-speed motors. Two or more of these feeders are in series on each belt, so that one or more materials may be fed simultaneously, thus securing a uniform feed from the receiving bins to the concentrator and from the mixing bins to the roasters.

Three 30-in. x 14-ft. Link-Belt pan conveyors are used for feeding the cone crushers. Materials from bins ahead of the rolls and vibrating screens are fed through roll feeders with arc gates, or rack-and-pinion gates. (See Fig. 3.) On the concentrator bins a special type of gate was devised, consisting of several rotating blades on a shaft, driven through a variable-speed mechanism. (See Fig. 4.)

Wherever hot materials are to be handled, and in a few other locations, conveying is accomplished by means of drag conveyors or spiral ribbon conveyors. Beneath the Cottrell plant all dust is conveyed, by nine 14-in. spiral ribbon Link-Belt Style B conveyors in dust-tight steel housings, to a central point, where it is discharged into a series of eight drag conveyors, which also take the flue dust from the bottoms of the roaster flues and discharge through pipes directly to the reverberatory furnaces. The hot calcine from the roasters is discharged, through closed pipes, to ten fettling conveyors of the chain drag type, one on each side of each reverberatory, and which are inclosed in dust-tight rectangular steel housings.

A number of pumping plants are provided for domestic, smelter, and concentrator water. The water for the concentrator plant is supplied from a lake about 2½ miles from the plant, through 12- and 16-in. cast-iron pipe lines about 12,000 ft. long. For pumping, De Laval two-stage pumps are used. A storage pond receives the water at the concentrator end, or it can be pumped directly to the head tanks in the top of the mill. Drainage water from the tailing ponds is returned to a settling pond for use in the mill, or wasted, in which case it eventually finds its way back to the lake.

In the construction of the concentrator building, to accord with the flow sheet at first contemplated, it was necessary to elevate the fine-ore bins very high above the ground and to provide an elevated platform, free from vibration, for the installation of Deister tables. The tops of the bins are therefore 72 ft. above the ground on which the bins rest, and the table floor is 33 ft. above the ground. A heavy concrete structure was constructed with reinforced columns, beams, and floor, upon which the steelwork for the bins was erected. These fine-ore storage bins are of steel with inclined bottoms 24 ft. wide, 29 ft. deep, and 400 ft. long, having a capacity of 14,000 tons of fine ore. A 36-in. electric-driven Stephens-Adamson tripper runs over them, and material is drawn out on each side by small steel gates and feeders of a special design, spaced 8 ft. apart on each side of the bin. These feeders are driven by variable-speed drives, so the rate of the feed can be regulated very closely to the requirements of the Marcy mills.

The flotation equipment includes 140 MacIntosh-type Geco flotation cells, in which all flotation work is conducted. Practically all handling of mill pulp is done with Wilfley pumps, the only bucket elevators being for floor clean-up work. A large part of the mill pulp is transferred from one process to the next, through black iron pipe, where the usual practice is to use launders. By this means it is possible to move the pulp with a very small difference in head. The only precautions taken are to maintain a small gradient in the direction of the flow and to use large radius bends, made either from the pipe or from cast-iron fittings.

The overflows from eight bowls—one-half of the total mill—are combined and conducted by a closed pipe system to one central discharge point, at which the stream is automatically sampled. After the addition of flotation reagents the stream is conducted by inverted-siphon pipe of 14-in. inside diameter to the bottom of an eight-compartment circular distributor. From each compartment an equal portion is piped to eight 20-ft. Geco flotation machines. A compelling reason for this piping arrangement was lack of fall sufficient for proper laundering, and the only other apparent solution of the problem was the use of additional pumps—an undesirable and expensive method. This piping system has worked out so well that it might prove preferable even though sufficient fall for launders were available. Fig. 5

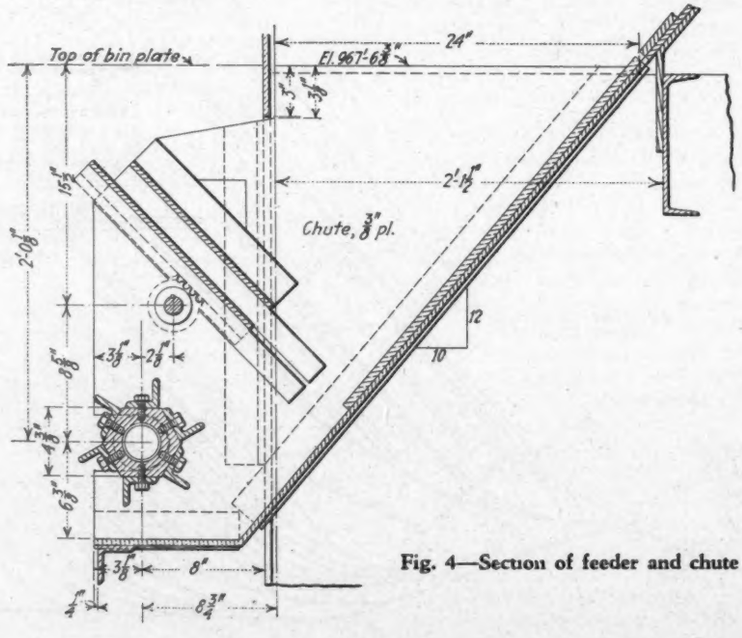


Fig. 4—Section of feeder and chute

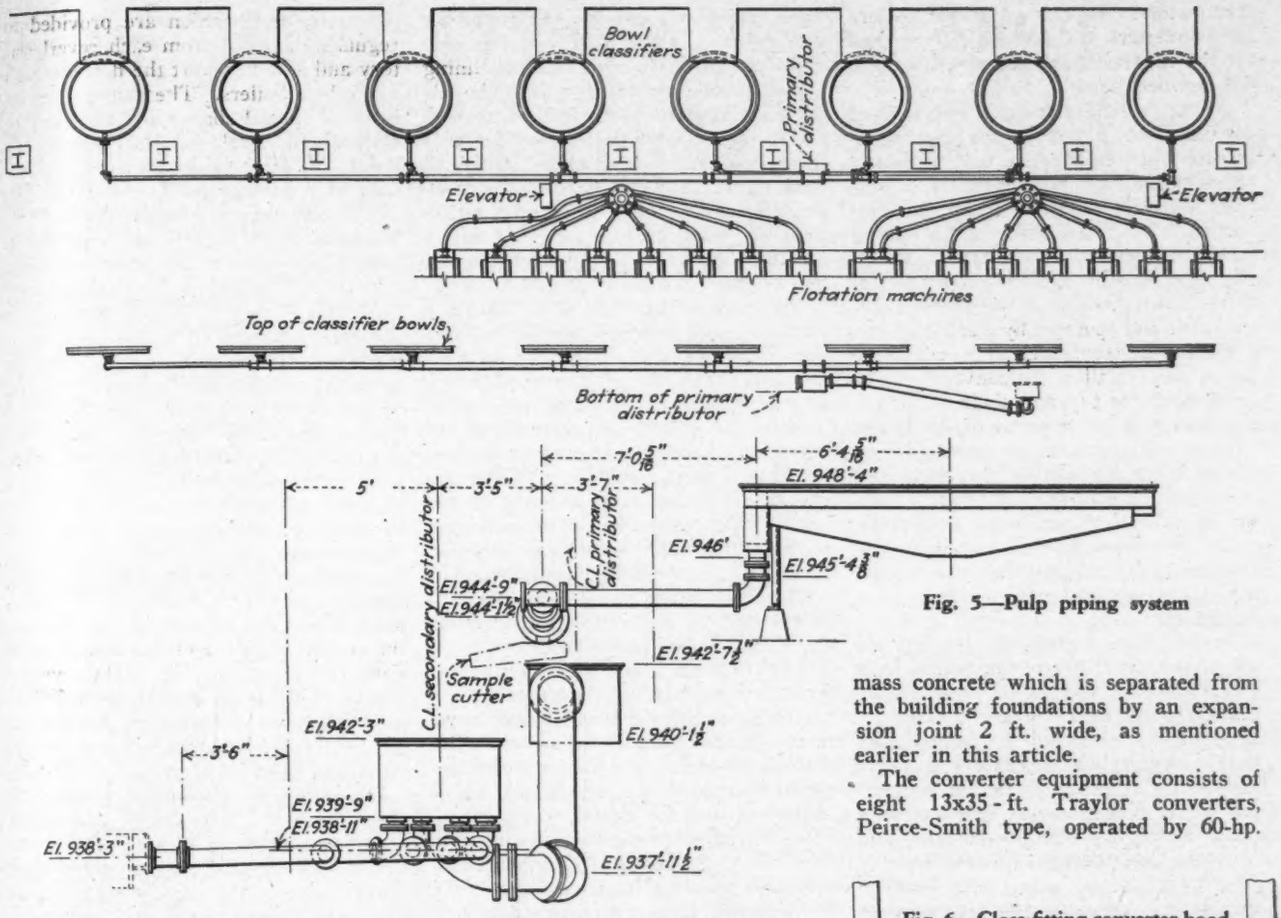


Fig. 5—Pulp piping system

shows the detailed layout of this system.

Dewatering is accomplished in seven 55x18-ft. Dorrco tray thickeners, six Dorr classifiers, and six 14-ft. diameter by 16-ft. Dorrco filters.

A 75-ton crane runs over the Marcy mills and the filters. The flotation machines are served by small hand cranes.

Fresh and return water are pumped from storage and settling ponds, by De Laval pumps, to elevated tanks in the top of the mill.

The copper and nickel concentrates are belt-conveyed direct to the roaster bins or to the concentrate storage bins. These storage bins have sloping V-bottoms at 50 deg., and a continuous slot in the bottom the length of the bins, making it necessary to design the columns for bending from the base, and to provide heavy ties under the floor between opposite columns.

The capacities of the bins are 6,000 tons of nickel-copper and 1,200 tons of copper concentrate. All the bins are filled from belt conveyors and trippers, and material is drawn off onto belt conveyors underneath.

In the smelter building are thirty Nichols-Herreshoff roasters, built by the Dominion Bridge Company, of Montreal. Each roaster is driven by a separate 20-hp. slip-ring motor. Cooling of the central shaft and arms is accomplished by six 40,000-cu.ft. per minute Sturtevant fans discharging into a common header, so that any group of six roasters may be served by any fan, or from the common header.

The reverberatory plant consists of five furnaces, the hearth dimensions being 24x110 ft. Slag is skimmed off directly into steel pots on cars, moved by car pullers onto the main standard-gage tracks, and from there to the slag dump by electric locomotives in trains of eight to twelve cars. Dumping is electrically controlled.

Reverberatory matte is tapped into 30-ton cast-steel ladles, mounted on transfer cars running in tunnels between the reverberatories. They are pulled by electric car pullers into the converter aisle, and from there lifted by 50-ton cranes to the converters.

The reverberatory furnaces are heavily buckstayed and rodded. The slag end is held at the bottom by heavy beams and tierods, which are, in turn, anchored to massive concrete blocks at each side of the furnace. At the firing end the buckstays abut, at their bottom ends, against a huge block of concrete, filled with old steel rail and weighing 113 tons. This is free to move toward the converter aisle if the longitudinal pressure of the furnace is sufficient to overcome the frictional resistance of the mass on its concrete base, from which it is separated by a tar-paper joint. The side buckstays abut at their bottoms against a steel channel supported by mass concrete which is separated from the building foundations by an expansion joint 2 ft. wide, as mentioned earlier in this article.

The converter equipment consists of eight 13x35-ft. Traylor converters, Peirce-Smith type, operated by 60-hp.

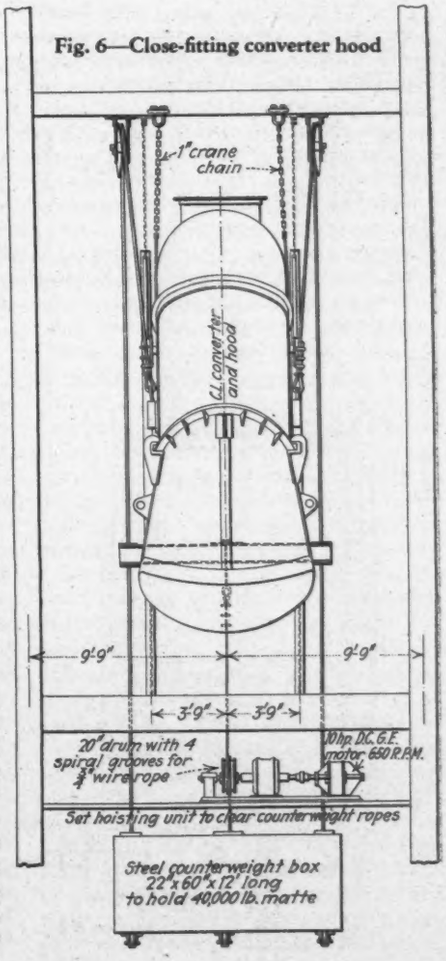

1" crane chain
C.L. converter and hood
9'-9"
9'-9"
3'-9"
3'-9"
20" drum with 4 spiral grooves for 3/4" wire rope
10 hp. D.C. G.E. motor, 690 R.P.M.
Set hoisting unit to clear counterweight ropes
Steel counterweight box 22"x60"x12' long to hold 40,000 lb. matte

Fig. 6—Close-fitting converter hood

d.c. motors. In case of power failure the converters are automatically turned off the tuyères by the energy stored in the flywheel sets.

A part of the converter gas is used by Canadian Industries for the manufacture of sulphuric acid, making necessary a high concentration of sulphur dioxide delivered from the converters. To accomplish this, a special hood was devised (see Fig. 6), which fits tightly over the converter mouth when blowing. The hoods are counterweighted and operated by electric hoists. They lift automatically 2 ft. when the power fails, to allow the converter shells to turn off the tuyères; their maximum travel is 4 ft., at a speed of 25 ft. per minute. The gas to the acid plant is drawn from the top of the hood and from the center of the gas stream into a separate flue leading to the acid plant.

The converter aisle is served by two Dominion Bridge Company cranes each having two 50-ton main hooks and a 10-ton auxiliary.

In the smelting group the roasters are above the reverberatory furnaces in a single building, and the converters in an attached structure. Since the buildings are completely inclosed, it was necessary to take extraordinary measures to ensure the escape of fumes from the converters while turning down, when tapping matte and slag from the reverbs, and from the hot calcine. To take care of this, tile partitions were placed between the roasters and converter aisles and at other points where gases were to be excluded from working floors. In addition, ventilating stacks were placed above the matte-casting aisle, the converter aisle, the roasters and the reverberatory slag aisles. The stacks are of large diameter and of a sufficient height to cause an induced draft from the warmer air in the building. This method has proved vastly superior to the monitor-type of building, and the structures have been remarkably free from gas.

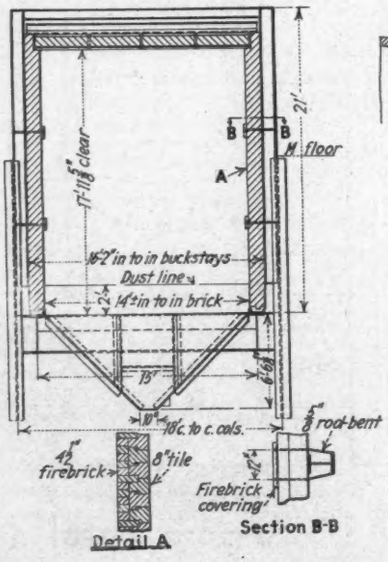
Two novel features of construction were introduced into the design of the flue system. (See Fig. 7.) The side walls consist of 4 in. of firebrick lining and 8 in. of interlocking tile. The tile is of a vitreous burn, laid in fireclay and cement. Owing to the fact that these flues are supported on structural steel 122 ft. above the ground, the brick and tile construction was adopted, rather than all brick, to save weight; and a considerable saving in the steel supporting structure resulted.

The roof consists of 9-in. firebrick arches against cast-iron skewbacks. The skewbacks are cast in short T-sections and bolted to the bottom flanges of structural beams above the flue. This construction should be very resistant to corrosion, since only the cast iron and brick arch are in contact with the gas stream. The maximum velocity of gas in this flue system has been calculated to be 30 ft. per second for the 30 ten-hearth Herreshoff roasters.

Flue dust from the roaster flues is carried by 730 ft. of drag conveyors to the reverbs as already mentioned.

The Cottrell plant takes the gases from the roasters only, the converter and reverb gases going through separate systems. It was built in accordance with plans furnished by the Western Precipitation Company, of Los Angeles, which also furnished the electrical equipment. The floor of the precipitator is supported over the converter dust chamber at an elevation of 104 ft. 6 in. above the smelter yard level. A novel feature of construction consists of vitrified interlocking tile as partitions between the treater units. The Cottrell plant is housed in a steel frame building with interlocking tile walls, and wood roof treated with zinc chloride.

Reverberatory flues connect to a main header flue with openings at each end into connecting flues entering opposite sides of the stack. All flues are of brick, supported 8 ft. above ground on concrete columns and beams, with steel hop-



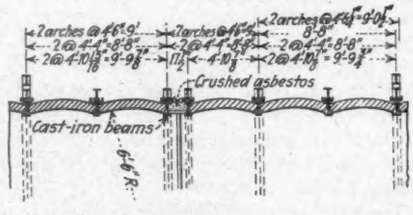


Fig. 7—Typical section of roaster branch flue

per bottoms, and cross brick arches supported on 16-in. H-beams at 5-ft. centers. There is a track underneath each flue for dust removal. The connecting flues from each reverb are 8 ft. high at side walls and 9 ft. 2 in. at center, 12 ft. wide. Each flue is 51 ft. 3½ in. long. Its walls consist of 16 in. of firebrick and the roof is of firebrick-cramped arches 9 in. deep. The arches rest on steelwork independent of the walls. The floor is of brick, and clean-out doors are provided along the sides. Lift dampers of special construction are provided to regulate the draft from each reverberatory and also to divert the flow through waste-heat boilers. The dampers are of brick of special shapes and are held together with steel rods inclosed in the brick, so that no steelwork comes in contact with the hot gases.

The reverberatory header flue is 15 ft. wide and 20 ft. high inside, and 378 ft. long. Two main branch flues are 18 ft. wide and 20 ft. high inside, and each one is 206 ft. long. The flues have five dampers arranged so as to direct the gases of all or part of the furnaces through either branch to the stack. These dampers are lifted and lowered from a steel frame, by chain blocks, and are constructed of a steel frame covered with expanded metal. A solid slab of "Celite" was cast between and over the surfaces of expanded metal. Since the dampers are either entirely out of the gas stream, or else blocking the flow entirely, it was felt that the temperatures would not be sufficient to destroy the cement binder, and this construction gave a comparatively light weight damper with, at the same time, sufficient heat resistance. Maximum velocity of gas in this flue system will not exceed 30 ft. per second.

Converter flues take the gases from eight 13x35-ft. Peirce-Smith converters. The flues are made of steel plate reinforced with external stiffener angles, and have a cross-section with a semicircular top, straight sides, and hopper V-bottom. The system consists of a header flue 425 ft. long, 15 ft. wide, and 25 ft. deep, and a cross flue 324 ft. long, 20 ft. wide, and 28 ft. deep, which discharges into a converter dust chamber.

The dust chamber has brick side walls, steel roof, and hopper V-bottoms, supported on steel columns and served by tracks for drawing out dust. Gas is distributed by two internal V-flues with adjustable cast-iron doors for regulating the width of the slot at the bottom. The chamber measures 23 ft. high inside, above hoppers, 60 ft. wide, and 162 ft. long, with provisions for enlarging if necessary. Maximum velocity will not exceed 3½ ft. per second.

In conclusion, I would like to pay tribute to the work done by my aids on the engineering staff in the field and in the drafting office. T. D. Price was in charge of all field survey work, and S. A. Crandall was chief draftsman. With a comparatively small force of field engineers, draftsmen, and designers, a tremendous amount of work was accomplished in a comparatively short time. Not only were plans made and specifications written, and purchasing requisitions issued for the work described in the foregoing, but plans were being carried on for various other projects of considerable magnitude. Too often the engineering draftsman's ingenuity, his meticulous consideration of the smallest details, and the accuracy required to avoid field mistakes, go unrecognized.

SELECTIVE FLOTATION MILL AT COPPER CLIFF

—*Wm. T. MacDonald*

Mill Superintendent

THOUGH preliminary test work with flotation of copper-nickel sulphide ores was begun approximately fifteen years ago, successful application of the process on a large scale was achieved only recently, when the new Copper Cliff concentrator of International Nickel was put into operation. Sudbury, therefore, is possibly the last remaining mining camp in North America of any importance where direct smelting of ore has continued until now as a major operation.

Two factors militated against the adoption of flotation for these nickel-copper ores; one was the comparatively high grade of the material, which made direct smelting in blast furnaces profitable; the other was the difficulty of separating the copper from the nickel. Another factor — very cheap power — was a corollary of the first, making waste-heat boilers, commonly used in connection with the reverberatory smelting of concentrate, without any specially attractive economical features.

The Mond Nickel Company, at its Coniston smelter, put up a small concentration plant for experimental purposes in 1914, which has operated continuously since, reaching a maximum capacity of about 400 tons per day. Although flotation was, perhaps, the principal concentration method employed, a preliminary magnetic separation was often made and table concentration was also employed. Treatment of mixed ores from the Garson and Levack mines—a mill feed averaging 1.55 per cent copper and 1.57 per cent nickel—gave the following typical results: Flotation concentrate, 5.77 per cent copper and 4.56 per cent nickel; table concentrate, 2.62 per cent copper and 4.50 per cent nickel; magnetic concentrate, 1.59 per cent copper and 2.59 per cent nickel; and tailing, 0.08 per cent copper and 0.29 per cent nickel. Bulk flotation of the copper and nickel sulphide was practiced with no attempt at selective separation; the concentrate was sintered with other material and smelted in blast furnaces. The Coniston mill is still in operation, but its feed now consists principally of ores from a stockpile.

International Nickel began laboratory tests on concentration in 1918, but the results were not particularly promising. However, a few years later the work was continued, and in 1925 a small 50-ton pilot mill was completed. This plant was operated for several months during the years 1925-27, under the supervision of W. M. Stephen. About that time the famous Creighton orebody showed signs of approaching exhaustion (although, more recently, large new orebodies have been developed there), so the ore from the upper levels of the Frood mine, averaging about 1.40 per cent copper and 1.50 per cent nickel, was the material used in the pilot mill. Operating results over a period of several months gave an average ratio of concentration of 3.2:1 with a tailing assaying 0.09 per cent copper and 0.22 per cent nickel, and indicated recoveries of copper and nickel of 95.7 and 90.9 per cent respectively.

Following the discovery and preliminary development of the enormous new orebodies in Frood, a large increase in reduction-plant equipment was decided upon. Improvements made in flotation practice, and also in economic smelting of fine material, appeared to make feasible concentration of ore even richer than had been treated directly in blast furnaces. Therefore a 4,000-ton concentrator was designed, in which roughing tables were to be used prior to flotation, removing a coarse copper-nickel concentrate. The table tailing after grinding was to be subjected to bulk flotation. In the final design, however, tables were used not as roughers preceding flotation but as scavengers following flotation.

The possibilities of selective flotation of the copper and nickel minerals—previously not accorded adequate consideration—were now more fully investigated by laboratory methods. This work, and large-scale tests made at the Coniston concentrator under my direction, indicated that a much more complete separation of copper and nickel could probably be effected than had theretofore been thought practicable. In these tests, on Frood ore containing approximately 4.5 per cent copper and 2.25 per cent nickel, at times a concentrate was produced containing approximately 28 per cent copper and 1 per cent nickel, with a recovery of about one-third of the total copper contained in the original feed. As a result of this test work, a recovery of half the copper contained in ore of this character might reasonably be expected in a properly designed and equipped plant, as a flotation concentrate assaying approximately 25 per cent copper and 1.25 per cent nickel. Furthermore, most of the remaining copper and nickel should be recoverable as a lower-grade nickel-copper concentrate with a total combined ratio of concentration of about 2:1. This gave an entirely new aspect to the problem, for if the copper-nickel ratio in the first concentrate could be maintained at 15:1 or 20:1, with a reasonable chance of recovering half of the original copper in this concentrate. the possibility presented itself to smelt this material as a copper ore, slagging off the comparatively small amount of nickel in basic-lined converters and recovering it in nickel converters, or as a byproduct in regular copper refining. Thus half of the copper contained in the ore would be eliminated from the comparatively costly process of copper-nickel separation. The decision was therefore made to double the capacity of the proposed concentrator (to 8,000 tons per day) to permit treatment of the entire mine production sent to Copper Cliff, with the exception of a small tonnage of coarse ore to be used in the blast-furnace smelting of certain smelter reverts.

Detailed plans for the new concentrating plant had been in course of preparation for some time, under the supervision of L. M. Sheridan, chief engineer, assisted by various members of the staff, and orders for practically all essential equipment had been placed by the summer of 1929. The crushing plant was nearing completion at the end of that year, and rock excavation and concrete foundations for the main concentrator building were also well along.

Table I—Dimensions and Areas of Concentrator Buildings

	Extreme Length, feet	Extreme Width, feet	Average Width, feet	Ground Floor Area, square feet
Receiving bins	320	35	35	11,000
Crushing plant	154	94	84	13,000
Screening plant	128	64	62	8,000
Concentrator main building	975	311	160	157,000
Additional conveyor-ways				21,000
Total				210,000

On Jan. 2, 1930, erection of structural steel commenced on the main concentrator building, and subsequent construction work proceeded rapidly. Concentrate production from the new mill started on Aug. 15, 1930, when the first 500-ton unit was placed in operation, and during the latter part of September about 3,500 tons of ore was treated daily. By the beginning of the coming year the full rated capacity of 8,000 tons per day can be made available, should the demand for nickel and copper then justify capacity operation. Fig. 1, p. 461, shows a general plan of the main concentrator buildings, and Table I, above, gives the outside dimensions and areas of most of the structures.

There are 39 conveyors, aggregating 7,700 ft. in combined length, measured between end-pulley centers. The total length of conveyor belting used, therefore, amounts to slightly more than double this footage, or approximately 16,000 ft.—just above 3 miles. This length is made up of 18-, 24-, 36-, and 48-in. belts of the following respective lengths: 400, 3,400, 10,300, and 1,900 ft.

The cold winters bring a building problem unknown to those accustomed to conditions in warmer climes. Windows are not so numerous, but ample electric lighting is provided. Air heaters are installed at numerous places where need for them is likely to arise. These are of the Aero unit type, and each consists of a series of steam-heated coils, behind which a motor-driven fan is placed for circulation of the heated air through the plant. Ample steam is available from the reverberatory waste-heat boilers.

Building design and equipment were naturally much influenced by the generally flat nature of the country in the vicinity of the logical mill site. But little surface soil was present, and the excavations for the foundations of all concentrator buildings were blasted from virgin rock.

All the main products throughout the plant are sampled automatically, a total of 31 samplers being used. The sample-receiving buckets are inclosed in protected boxes through which flexible hoses connect to the sample cut. All samples from the flotation section are handled separately, and are first cut to a uniform quantity in a locally designed wet splitter. They are then filtered through one of six Denver laboratory vacuum filters, which are of material assistance in speeding up the preparation of samples. High-grade and low-grade products are kept separate throughout their entire handling, duplication of the essential equipment making this possible. After filtering, the filter cakes are dried in two electric ovens of local make, and are then cut down, reduced on a bucking board to 80 mesh, and sent to the assay office. Disk pulverizers are not necessary, because of the fineness of all the flotation products. Daily screening tests on both flotation feed and final tailing, by shifts, are made for control purposes. A full set of Tyler standard screens and a Ro-Tap machine are provided for screen tests. All dry samples —and those wet samples not calling for daily analysis—are handled separately in another room by additional equipment. Two of the chain-and-bucket samplers discharge directly into this room through closed pipes. A Braun Chipmunk crusher and a disk pulverizer are here employed for reducing the coarser samples, and another electric drying oven is in service. Samples for monthly composite analyses are prepared and stored in this room. Three 12,000-gal. steel tanks, housed in a separate brick and concrete building, are provided for the storage of liquid flotation reagents. One of these tanks is divided into two 6,000-gal. compartments. From the storage tanks the reagents are pumped to smaller intermediate tanks within the mill building, above the flotation floor, whence they are distributed by gravity through smaller pipelines to the various automatic feeders, where control float valves are employed. The flotation system is served by 26 of these individually motor-driven feeders handling the various oils and other reagents.

Steam-distilled pine oil and No. 80 Pensacola oil arrive in tank cars, and the various other liquid reagents are received in drums. Bear Brand sodium xanthate, copper sulphate crystals (a product from International Nickel's English refinery), and burned lime are also purchased in carload lots. The xanthate is received and stored in a room provided with an overhead crawl, solution tank, and pumping equipment. Here a concentrated solution is made up and pumped to a main storage tank in the flotation department, where it is diluted to desired strength and delivered by gravity through a system of pipes to the feeders.

Milk of lime is prepared in a separate apartment in the mill building. The lime cars, delivered alongside the lime-handling plant, are emptied with a short portable conveyor belt into a No. 2 McCully gyratory crusher. The crushed product is taken by an elevator to a 125-ton steel bin, from which an adjustable feeder and a short conveyor belt deliver it to a 3x8-ft. Marcy rod mill operating in closed circuit with a small Dorr drag classifier. Water as required is added to the mill feed, and the classifier overflow goes to an intermediate steel storage tank, from which it is handled by a Southwestern-Littlewood 3-in. pump to the main lime-emulsion storage tank near the flotation cells. This tank holds approximately 15,000 gal. and is equipped with two sets of gear-driven paddle-arm agitators and a small motor. Here the solution is diluted to the required strength, and forced through distributing pipes to any desired point of the grinding and flotation systems by a pump connected to the bottom of the tank. A return pipe conducts excess solution back to the storage tank. Lime solution is first added to each Marcy mill feed, which insures a protective alkalinity at all points of the grinding circuit.

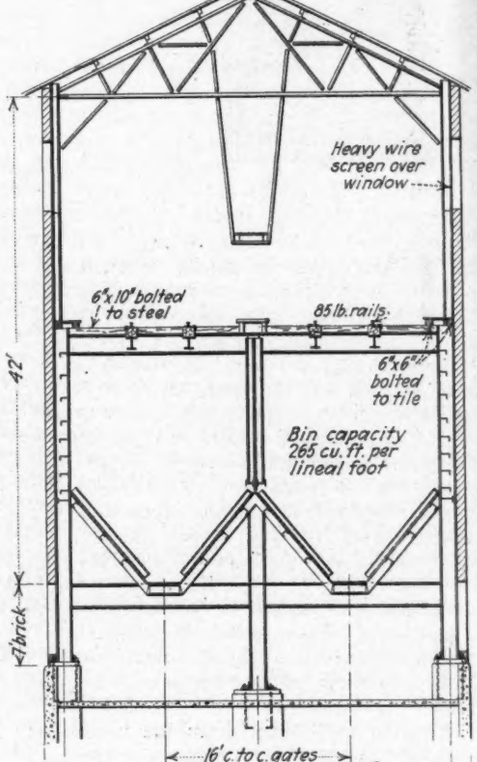


Fig. 1—Cross-section of receiving bins

Alkalinity control is regulated and maintained by the use of a LaMotte Roulette Comparator, readings being taken every half hour. At present the alkalinity of the original flotation feed is being kept at a *pH* value of from 8.0 to 8.5, although sufficient oppor-

tunity to determine the optimum operating range for any of the mill solutions has not yet existed. Table II shows average *pH* determinations made on certain mill waters and pulps during September. Some of these will, of course, vary widely in future operations.

Table II—Alkalinities of Mill Solutions

	pH Value
Kelley Lake, fresh water supply	6.8
Thickener overflow	8.0
Wash water in flotation cell launders	6.7
Bowl overflow; feed to copper cells	8.2
Feed to nickel-copper cells	7.6
Final tailing	7.4
Copper cleaner feed	8.6
Copper secondary cleaner feed	8.8
Tailing pond, 200 ft. north of dam	6.1

Pulp densities are checked by hourly readings on the overflow from each bowl classifier, as well as at other desirable points throughout the circuit. At present, the original flotation feed varies from 27 to 35 per cent solids; all pulp densities are, however, still subject to much experimentation.

Incorporated in the main building, and adjoining the mill offices, is a complete, well-equipped experimental laboratory. This includes a Geco continuous fine-grinding and flotation plant of laboratory size, composed of a 14x16-in. ball mill in closed circuit with a 4x38-in. drag classifier; two pneumatic roughing, and three cleaning, cells of appropriate size, and a small Wilfley table, together with an air-blower, ore and reagent feeders, motors, and other auxiliary equipment. This plant is capable of treating from 40 to 60 lb. of ore per hour, when receiving feed of about ¼-in., grinding it to 65 or 70 per cent through 200 mesh. An adjacent room is available for microscopic work.

Near-by lakes provide abundant water supply. Original fresh water is now being pumped about 3 miles from Kelley Lake, and is stored in a large fresh-water reservoir near the mill, from which it runs by gravity to the clear-water sumps. It is then pumped to elevated supply tanks, assuring ample and even pressure for all milling purposes. Arrangements of pipelines are such that, if desired, the lake water can be pumped directly to fresh-water sumps in the mill. A long narrow sump extends beneath and throughout almost the entire length of the seven 55-ft. thickeners of the concentrate dewatering plants, which are placed in one row. This sump serves to collect all circulating water in the mill, including the clear water which is recovered from the tailing pond. Five 1,500-g.p.m. centrifugal pumps are installed; three of these handle return water; one is for fresh water; and one may be used for either purpose. Of the total amount of water used for milling (estimated at approximately 1,500 g.p.m.) about one-third is expected to be from fresh supply. The amounts of both original fresh water and of returned water from the tailing pond are measured by graphically recording Bailey flow meters.

With full-scale operation, most of the ore furnished to the mill will be from the Frood mine, with the remainder composed of varying proportions from other mines of the company. The mill feed should average approximately 4.4 per cent copper and 2.2 per cent nickel, with a precious-metal content (gold, silver, and platinum-group metals) of slightly over $4 per ton.

The copper is present as chalcopyrite —$CuFeS_2$—and nickel sulphide, pentlandite — $(FeNi)_nS_{n2}$ — accounts for practically all of the nickel. Pentlandite varies considerably in its composition, but in our ores many assays indicate an average of 36.0 per cent nickel, 30.4 per cent iron, and 33.6 per cent sulphur. Much pyrrhotite—Fe_nS_{n+1}—is present. According to average assays it occurs here in the form Fe_7S_8, containing 60.8 per cent iron and 39.2 per cent sulphur. The pyrrhotite is intimately associated with the pentlandite, but is reasonably free from chalcopyrite. The total sulphide content of the mill feed averages approximately 45 per cent. Experimental work has indicated that to obtain a high recovery of the nickel, copper, and precious metals, a recovery of practically all of the total sulphides is necessary. Therefore, a concentration ratio of 2:1 is as high as can be expected. The cleanest pyrrhotite yet separated has an average of close to 1 per cent nickel, but a low copper content.

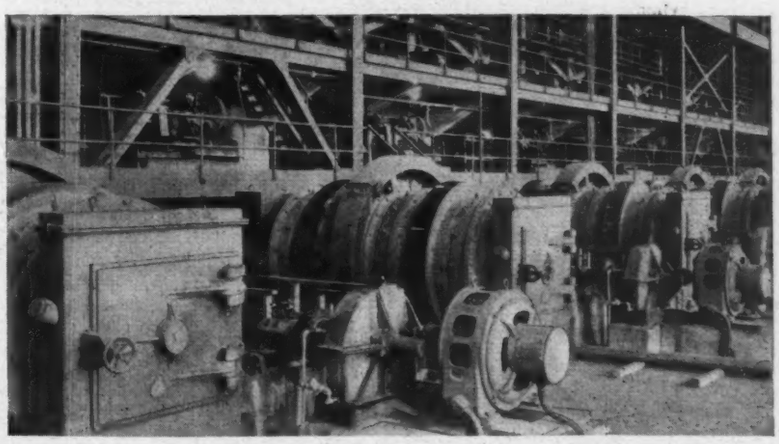
Distribution of the various precious metals in the original ores and in the different mill products is of considerable importance and will naturally be given much attention. At the present stage our operations do not permit the compilation and distribution of accurate detailed data, but the uniform, excellent recovery of the combined precious metals previously obtained by direct smelting of the raw ores does not appear to be endangered by the introduction of concentrating methods.

Fig. 2 outlines the flow sheet and lists much of the equipment now in service. It should be consulted, together with Fig. 1 on p. 474, for a better understanding of the following text. Additional details will be found elsewhere in the tables and data of this article, or in that appearing in this issue by L. M. Sheridan, on Engineering Design.

The ore is crushed at the mines to pass 5-in. grizzlies, or revolving trommels, and is then transported in standard-gage, 60- and 80-ton, Hart-Otis side-bottom dump cars hauled by 500-volt d.c. locomotives over the company railway, or by steam over the Canadian Pacific. The all-steel receiving bins, with a total capacity of 10,000 tons, are subdivided into twenty compartments, each holding 500 tons. These bins are 32-ft. wide, 308 ft. long, and 34 ft. high, have V-bottoms, and are lined throughout, on both sides and bottoms, with 60-lb. rails. Sand for flux, smelter flue dust, mine-screen undersize, and trommel or grizzly oversize, are kept separate in the individual compartments.

To prevent freezing of ore in the winter, or to thaw ore that has become frozen in storage, steam pipes are provided underneath throughout the entire length of the bins. Ample steam for this purpose is available from the reverberatory waste-heat boilers. Ore received averages between 2 and 3 per cent moisture. Forty bottom chutes, served by four traveling, motor-driven, conveyor-belt feeders of local design, discharge the ore on a 36-in. conveyor belt system which delivers it to hopper-bottom storage bins above the three 7-ft. cone crushers. During this transportation, two 45-in. circular magnets remove tramp iron. These are, however, placed at such a distance from the conveyor belts that practically none of the magnetic portion of the ore is removed. This magnetic quality precludes the use of magnetic pulleys. Provision is made for the conveying, when desired, of material from the main receiving bins directly to the intermediate smelter mixing bins, where fluxing sand, lime, flue dust, and other materials are stored separately. These materials are discharged by bottom

Grinding mills, with classifiers in rear and table floor above



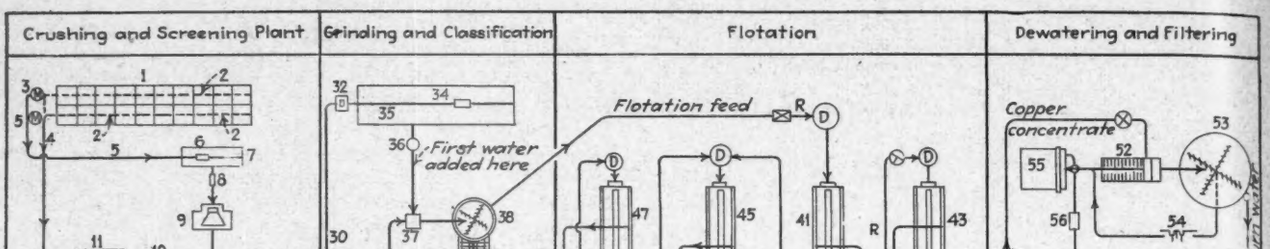


Fig. 2—Flow sheet, with equipment, for 8,000-ton concentrator

1. 10,000-ton receiving bin, divided into 20 500-ton compartments
2. 40 bottom chutes, served by four traveling belt-conveyor feeders, of local design
3. Two 45-in. suspended magnets, made by the Electric Controller & Manufacturing Company
4. Conveyor-belt system, direct to smelter
5. Five 36-in. belt conveyors; two in parallel, followed by three in series
6. One 36-in. Stephens-Adamson, motor-driven traveling tripper
7. 1,200-ton storage bins; three bottom hoppers
8. Three steel-flight caterpillar feeders
9. Three 7-ft. Symons cone crushers; each gear-driven at 235 r.p.m. by a 200-hp. motor
10. Two 36-in. belt conveyors, in series
11. One 36-in. traveling tripper, same as (6)
12. 600-ton bins, V-bottoms, eight discharges
13. Eight drum-type feeders; local design
14. Eight Traylor "Supreme" vibrating screens, 9-mesh undersize, slot-opening wire cloth
15. Two 36-in. belt conveyors, in series; with one intervening 22-in. magnet, same as (3)
16. One 36-in. traveling tripper, same as (6)
17. Two bins, 450 tons each, hopper bottoms
18. Two drum-type feeders, local design
19. Two primary 78x18-in. Traylor rolls; each pulley belt-driven at 103 r.p.m. by a 200-hp. motor (400 hp. per roll). Set at ¾-in.
20. Two 48-in. belt conveyors, in series.
21. One 48-in. traveling tripper, same as (6)
22. 1,500-ton bins, V-bottoms, 24 discharges
23. 24 drum-type feeders, identical with (13)
24. 24 vibrating screens, identical with (14)
25. Two 48-in. belt conveyors, in series; with one intervening 45-in. magnet, same as (3)
26. One 48-in. traveling tripper, same as (6)
27. Three bins, 450 tons each, hopper bottoms
28. Three drum-type feeders, identical with (18)
29. Two secondary rolls, identical with (19), but set at ⅝-in. and each pulley belt-driven by a 100-hp. motor (200 hp. per roll)
30. Eight belt conveyors, varying widths, transporting screen undersize to mill bins
31. Three Merrick weightometers
32. Automatic sampler; chain and bucket type
33. Dust-control system, serving crushing and screening departments

NOTE: Automatic oil feed and Bowser filtering systems employed on all crushers and rolls. Two 20-ton Pawling & Harnischfeger power cranes serve the crushers and rolls.

32. Automatic sampler, chain and bucket
34. One 36-in. tripper, same as (6)
35. 14,000-ton, A-bottom storage bins
36. 96 revolving feeders; shaft and angle-iron type. Local design
37. 16 junction boxes
38. 16 12-ft. Dorrco bowl classifiers. Varying rake speeds used
39. 16 Marcy roller mills. 6 ft. 6 in. x 12 ft. 6 in. inside liners. Single scoop feeders; 17 r.p.m.; each mill gear-driven through Falk reduction gears by a 200-hp. motor. Equipped for employing either rods or balls
40. 32 3-in. Wilfley sand pumps. One in service, and one spare, for each Marcy mill

NOTE: Automatic, gravity pressure, central oiling system, serves all mills. Bowser oil-filtering equipment used. A 75-ton Pauling & Harnischfeger power crane serves all Marcy mills, and also the dewatering plant equipment.

41. Copper section; primary roughers. Sixteen Geco (MacIntosh type) flotation cells; 30 in. wide, rotors 9 in. diameter, 20 ft. long. Perforated rubber covers. Individually driven at 16 r.p.m. by 2-hp. motors and reduction gears
42. Copper section; secondary roughers, Sixteen flotation cells, identical with (41)
43. Copper section; primary cleaners. Sixteen flotation cells, identical with (41), except 36 in. wide and 12 ft. long.
44. Copper section; secondary cleaners. Sixteen flotation cells, identical with (43)
45. Nickel-copper section; primary roughers. Sixteen flotation cells, identical with (41)
46. Nickel-copper section; secondary roughers. Sixteen flotation cells, identical with (41)
47. Nickel-copper section; cleaners. Sixteen flotation cells, identical with (43)
48. Nickel-copper section; cleaners. Sixteen flotation cells, identical with (43)
49. Scavengers, six flotation cells, identical with (41)
50. 48 Deister Plat-O tables. Individually driven at 265 strokes per minute by 3-hp. motors and short Tex-rope drives. Stroke, 1⅛ in.
51. Four Roots blowers, furnishing flotation air at 2¼ lb. Air pressure used at cells, 1¾ to 2 lb.

    21 Automatic samplers: General Engineering Company Geco type; individually motor-driven

    7 Automatic samplers: Galigher Company, Geary-Jennings type; individually motor driven, controlled by one master timer

R.—Automatic reagent feeders. Seventeen Geco type; 6 Southwestern Engineering Company; and 2 Galigher-Geary.

D.—Ten circular, bottom-fed, compartment distributors.

P.—70 Wilfley sand pumps; 2-in., 3-in., 4-in. and 6-in. sizes.

NOTE: In addition to the above flotation cells, a 500-ton experimental plant serving Mill Unit No. 1 employs two 20-ft. and four 12-ft. Geco cells, identical with (41) and (43). Such plant equipped with reagent feeders, automatic samplers, and pumps, elsewhere enumerated. Two overhead crawls, with 1-ton chain blocks, serve all flotation cells

52. Two 8-in. x 18-ft. 4-in. Dorrco duplex drag classifiers; variable stroke
53. Two 55-ft. diameter Dorrco tray thickeners. One revolution in 7 min.
54. Two Dorrco triplex pumps
55. Two 14x16-in. Dorrco filters. One revolution in 6 min.
56. One Merrick weightometer, 24-in.
57. Conveyor system either direct to the smelter or to mill storage bins
58. One 24-in. S-A automatic tripper
59. 1,200-ton copper concentrate bin
60. Conveyor system to smelter
61. Four classifiers, identical with (52)
62. Five thickeners, identical with (53)
63. Five pumps, identical with (54)
64. Four filters, identical with (55)
65. One Merrick weightometer, 24-in.
66. Conveyor system—either direct to the smelter or to mill storage bins
67. 36-in. traveling tripper, same as (6)
68. 6,000-ton nickel-copper concentrate bin
69. Conveyor system to smelter
70. Five 31x12-in. Ingersoll-Rand vacuum pumps, furnishing vacuum for filters
71. Five 1,500-g.p.m. DeLaval water pumps

NOTE: One each, of machines Nos. 52, 53, 54, and 55, can also be used for nickel-copper concentrate handling.

chutes, mixed as desired, passed over a weightometer and conveyed to the smelter — entirely bypassing the concentrator.

EACH cone crusher is supplied with ore from beneath the adjacent storage bin; and each is individually driven at 235 r.p.m. by a direct-connected 200-hp., 750-r.p.m. wound-rotor motor. Thus far, the power consumption per crusher, when handling from 250 to 300 tons per hour of 5-in. material and adjusted to deliver a product of approximately ¾- to 1-in. maximum size, has averaged about 120 hp. Two-shift operation (eight-hour shifts) has proved ample for all requirements so far. The regular oiling system—including direct-connected pump and filtering apparatus —supplied as standard equipment with each cone crusher, has so far given satisfactory results; but the additional installation of an auxiliary tank for gravity oil-feed to serve all three crushers is now being considered.

The crusher product is conveyed by two 36-in. belts to V-bottom storage bins, from which it is drawn by revolving, drum-type feeders individually serving eight 54-in. vibrating screens, now covered with wire cloth having rectangular openings, the narrow width of which measures 0.11 in. Approximately 15 per cent of the ore here is undersize, and the oversize is conveyed by belt to two hopper-bottom storage bins. Each bin is discharged by a drum-type feeder into one of the two primary 18x78-in. rolls, set to about ⅜-in., and making 103 r.p.m. As first installed, each roll pulley was driven through a short belt-and-tightener pulley by a 100-hp. 750-r.p.m., wound-rotor motor—a total of 200 hp. per complete roll—all of which power was called upon. This, however, did not permit the rolls to run at full capacity, or the use of choke feeding, and some corrugation and flanging of roll shells resulted. Carborundum grinding bricks were used to remove such flanges. Both primary rolls are now being equipped with 200-hp. driving motors for each pulley (400 hp. per roll), upon the completion of which choke feeding will be practiced, which is expected to improve operating conditions.

Roll bearings are of special design to permit the use of oil as a lubricant. An 800-gal. supply tank, with a gravity head of approximately 20 ft., delivers oil through sight feeders to all bearings of the five rolls in this department. Short lengths of flexible metallic hose are introduced in the oil-piping system at each roll, to compensate for shell wear and to withstand vibration. The oil used flows to a receiving tank, where it is heated and filtered, and is then transferred by a small centrifugal pump to the overhead supply tank.

THE primary roll product is conveyed to A-bottom bins above the 24 secondary vibrating screens, which use wire cloth identical with that on the primary screens. Screen oversize is returned by 48-in. conveyor belts to individual hopper-bottom storage bins above the three secondary 18x78-in. rolls. Each of the two separate conveyor systems transporting screen oversize has an additional magnet of the type previously described for removing small pieces of tramp iron not previously removed or that has been subsequently introduced into the circuit.

The secondary rolls, fed in the same manner as the primaries, are kept set as close to ⅜ in. as conditions permit, and are operated at 103 r.p.m. in closed circuit with the secondary screens, the products from both primary and secondary rolls being combined. Each roll pulley is belt-driven by a 100-hp. motor (200 hp. per roll), and the full power is regularly employed.

This completes the crushing and screening operation. The undersizes from all primary and secondary screens are combined, passed over weightometers, and conveyed either to the fine-ore storage bins, or, if desired, to the smelter mixing bins previously mentioned.

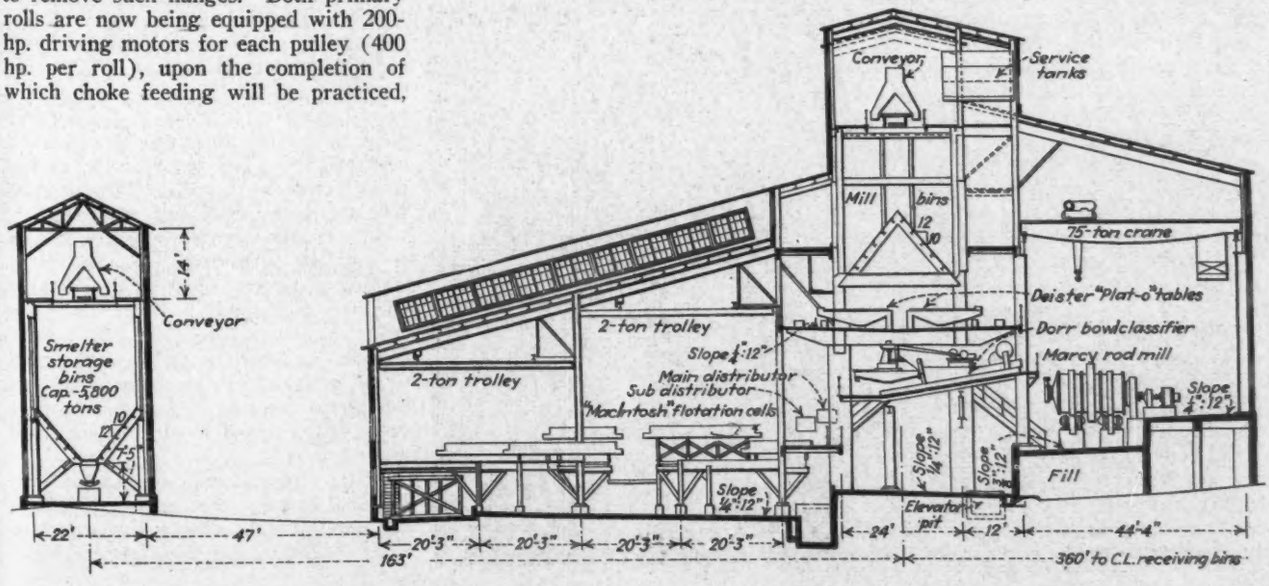
The degree of crushing practiced so far has been dictated largely by the requirements for proper roasting of the raw ore, and it is possible that when this ore is no longer sent directly to the roasters, a somewhat coarser product from the crushing plant may be preferable, to secure the best possible balance between the crushing plant and the fine-grinding department for economical operation.

Two 20-ton power cranes run the entire length of the crusher building, one serving the crusher, the other the rolls. Heavy supplies are delivered directly to both sections of the crusher building on standard-gage railway tracks. Practically all the power used in the crushing plant is 2,300 volts, 25 cycles; a comparatively small portion of it is supplied at 550 volts, 25 cycles, however.

A MODERN dust-control system designed by George E. Lynch serves both the crushing and screening plants. It is of the type used by practically all of the larger concentrators in the United States, and serves to eliminate floating dust in the air. The dust collected is immediately returned to the ore flow, about 80 per cent being removed by dry collectors and the remaining 20 per cent by a specially constructed spray tank. The suction fan, handling only clean air, is placed outside this spray tank. Equipment consists of one No. 45 Keith fan, furnished by the Sheldon Fan Company, capacity 50,000 cu.ft. per minute at 598 r.p.m., Tex-rope driven by a 75-hp. motor; one special spray tank, Lynch design; four cyclone dry collectors; and the necessary light sheet-steel piping.

The fine-grinding, flotation, and dewatering sections are housed in a

Fig. 3—Section through grinding and flotation division



separate building between the crushing plant and the smelter. This is a continuous structure, all under one roof, measuring 975 ft. total length. The grinding section is composed of eighteen 25-ft. bays, including a repair bay at each end of the building. Crushed ore for milling is stored in steel bins extending throughout the length of sixteen bays, and divided into individual compartments which permit separate storage of different ores for experimental purposes. Ore is removed from these mill bins by locally designed, small revolving-shaft and angle-iron feeders, six per mill unit. After addition of water the pulp is carried, by launders having a slope of 4½ in. per foot, to the feed wells of the individual bowl classifiers operating in closed circuit with the roller mills.

Sixteen rod mills, each 6½x12½ ft. inside new liners, are arranged in single file, each in closed circuit with a 12-ft. bowl classifier having a duplex-rake compartment 8 ft. wide by 18 ft. 4 in. long. Milk of lime is added to the circuit at the classifier discharge, which runs by gravity through launders to the single-scoop feeders. Automatic feeders placed at this point permit the addition of the first oils and other flotation reagents. The discharge from each mill is laundered to its own sump, from which a 3-in. sand pump returns it to the bowl classifier, joining the feed from the ore bins en route. The mills are of the latest design with two riding rings and manganese-steel wave-type liners.

All of the mills are constructed and equipped so that they may readily be used either as rod or ball mills. At the time of writing, however, only one of the eight mills in use has a ball charge. The original rod load consisted of 22 tons made up of 2½-in., 2-in., and 1½-in. diameter rods, all 12 ft. long. All renewals are made with 2½-in. rods. The initial ball-mill charge was 28 per cent 2-in., 28 per cent 2½-in., and 44 per cent 3-in. balls, but 3-in. balls only are used for renewals.

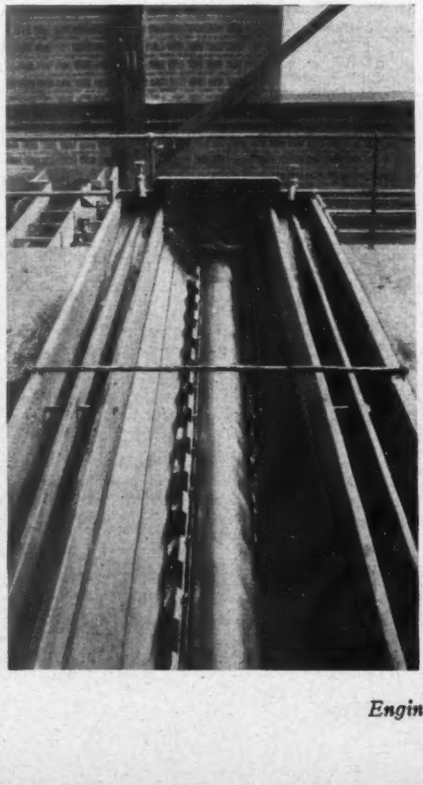
Each mill has a capacity of about 500 tons a day of original feed. It is driven by a 200-hp. motor through a reduction gear and makes 17 r.p.m., actually requiring about 185 hp. The use of direct-connected slow-speed synchronous motors for driving these mills was given serious consideration, but because of local conditions and the fact that all power supplied is of 25 cycles, higher-speed motors and reduction gears were finally decided upon, and this has so far proved satisfactory. A 75-ton power crane serves all rod mills and also the dewatering-plant equipment.

Chalcopyrite, which is the copper-bearing mineral in the ore, floats readily. To secure a copper concentrate relatively low in nickel, crowding of the rougher machines is practiced, with a minimum amount of reagents. No reagents are directly intended to depress the pentlandite or pyrrhotite. Pentlandite, the nickel sulphide, is less floatable than chalcopyrite, and the pyrrhotite is still more reluctant to float. As previously mentioned, however, most of the nickel is so intimately associated with the pyrrhotite—perhaps even in solid solution therein — that pyrrhotite apparently cannot be discarded in the tailing without appreciable loss of nickel. The intent is first to secure a copper concentrate with copper-nickel ratio of 15:1 or higher; and subsequently a nickel-copper concentrate of a suitable grade consonant with a low tailing loss.

Considerable latitude has been allowed for changes in the flow sheet. The rougher machines have all been equipped with a double concentrate launder (see illustration) to permit separate removal and disposal of different characters of froth from the same machine if this should prove advantageous. The concentrate launders of all cells have a slope of not less than 1½ in. per foot, and water spray pipes for the breaking down of froth are provided at the upper end of all these launders. Provision has been made for separate discharge of overflow from Unit No. 1 bowl classifier directly to a 500-ton experimental unit of four 20-ft. flotation roughers and four 12-ft. cleaner cells, with reagent feeders, conditioning tanks of the Pachuca type, pumps, sumps, and other accessories, so that almost any desired combination of treatment may be employed.

Original feed to the primary copper roughers carries from 27 to 35 per cent solids with a *pH* value of 8.0 to 8.5. Small additions of a mixture of G.N.S. No. 5 pine oil and No. 80 Pensacola oil have been made. Primary rougher feed enters at the rate of about 500 tons of ore per day per 20-ft. cell. The tailing from each primary rougher passes to a similar secondary rougher and the combined concentrate from the primary and secondary roughers—with the addition of further reagents when wanted — is pumped to the copper cleaner section, where it is given a double cleaning to produce finished copper concentrate. The copper cleaner section for each half of the mill consists of sixteen 12-ft. Geco cells. Two parallel rows, each of eight cells, are arranged so that either double, triple, or quadruple series cleaning can be practiced, although thus far primary and secondary cleaning only have been employed. Tailing from the primary copper cleaner machines is pumped to the nickel cleaners. The tailing from the secondary copper cleaners joins the final nickel concentrate.

Looking into a flotation machine, showing rotor and double launder

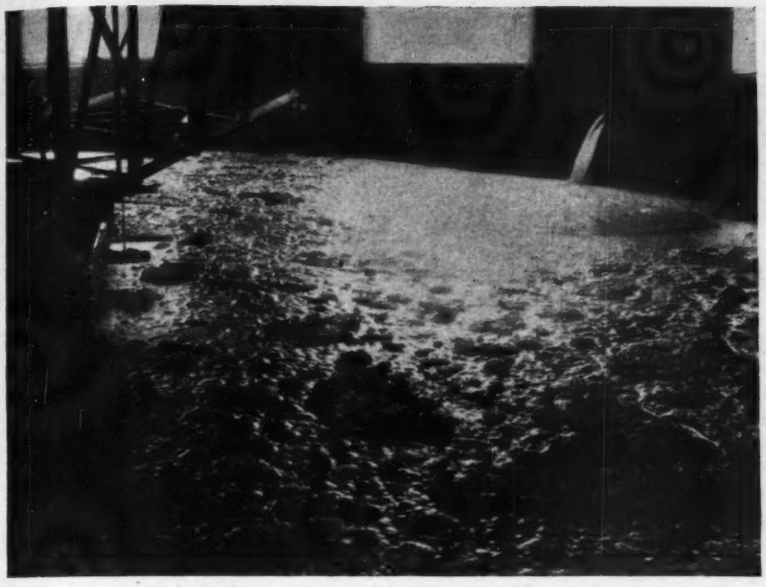


Tailing from the secondary copper roughers is pumped to the nickel-copper section for re-treatment, after addition of more flotation reagents, these being varying amounts of sodium xanthate, G.N.S. No. 5 pine oil, No. 80 Pensacola oil, copper sulphate, and at times either No. 25 or No. 15 Aerofloat. "Ketone residue" and "flotogen" (mercaptobenzothiazole) have also been used occasionally for experimental purposes. This nickel-copper roughing section consists of sixteen 20-ft. Geco cells, arranged in two rows of eight cells each. The tailing from the primary roughers is laundered direct to the secondaries, the secondary rougher tailing flows to three scavenger cells of the same type and dimensions, in each half of the mill.

The scavenger concentrate joins the combined concentrate from both primary and secondary nickel-copper roughers, and is pumped to the nickel-copper cleaners, which consist of sixteen 12-ft. cells where single cleaning only is practiced, although the cell arrangement is the same as in the copper-cleaning section, and additional cleaning can be practiced should occasion require. Tailing from the nickel-copper cleaners is added to the original feed to the nickel-copper roughers.

The tailing from the scavenger cells is pumped to a four-way distributor feeding a battery of 24 tables serving one half of the mill. These tables remove a low-grade nickel-iron-copper concentrate which is added to the final nickel-copper flotation concentrate, and the table tailing is laundered to a sump and pumped to the tailing pond by 6-in. pumps.

In the original mill design, the idea was to employ the tables ahead of flotation, but this scheme was discarded when selective flotation was adopted.



Sunset on a thickener

Provision was then made, however, for the 48 tables, originally ordered as roughers for a 4,000-ton plant, to be used in the present 8,000-ton plant as scavenger tables, treating the final flotation tailing. These tables are being operated intermittently, and the results obtained—both when they are operating and when they are shut down—will be compared to determine whether or not continued use in the present mill is justifiable.

The use of pneumatic flotation machines on such heavy sulphide ore as this would perhaps not have been considered feasible a few years ago; but it is believed that with the type of cell employed throughout this mill, fully as good metallurgical results will be obtained as though mechanically agitated machines were used. The power requirement for these cells is low compared with that needed by mechanically agitated machines of equal capacity, and the mechanical upkeep also promises to be small. All cell rotors are driven at 16 r.p.m. by individual 2-hp. motors through reduction gears. The cells are intentionally over-powered to provide for surge loads and to permit easy starting after forced shutdowns. The rotors are of punched sheet metal, and are 9 in. in diameter. Perforated rubber blankets are used as the porous media covering the rotors, the perforations of approximately 0.01-in. diameter, numbering about 200 per square inch. Although operating in a lime circuit, no perceptible interference with proper air distribution—such as might result from surface incrustation or blinding of perforations—has developed. Flotation air at the blowers is at 2¼-lb. pressure, but the actual pressure at the cells averages slightly under 2 lb., varying within narrow limits. Four of the cells of the experimental unit are equipped with orifice-type, Bailey indicating gas meters, for measuring the amount of air used.

Dewatering is more of a problem in this northern latitude, where the winter temperature remains below freezing for long periods, than it is in the Southwest. All dewatering equipment must be housed to prevent freezing. The final nickel-copper concentrate is pumped, at about 20 per cent solids, and after being automatically sampled, is discharged in a distributor, from which it can be delivered to any one of four 8-ft. by 18-ft. 4-in. duplex drag classifiers. Here the coarser material, amounting to about 20 per cent of the entering solids, is removed and delivered by a pipe system directly to the serving filter at 80 per cent solids. Classifier overflows, at about 15 per cent solids, are laundered to one or more of five 55-ft. diameter tray thickeners, 16 ft. deep. The clear solution from these thickeners is removed by pipe outlets tapped in just below the tray at four equidistant points around the tank periphery and piped to the return-water sumps.

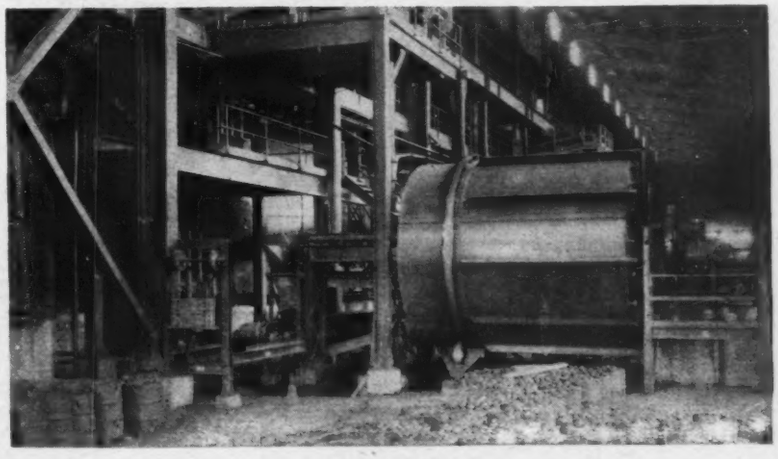
Discharge from all thickeners, averaging 50 per cent solids, is pumped by triplex pumps to a distributing box, from which it runs to the classifier rake discharge by gravity, and is sent to one of four 14-ft. diameter by 16-ft. filters of the inside-settling-drum type, where filter cake containing from 8 to 11 per cent moisture is obtained. This concentrate is transported by a belt conveyor, equipped with a weightometer, to an auxiliary belt-conveying system delivering it directly to the bins over the smelter roasters, or depositing it in the intermediate concentrate-storage bins.

The final copper concentrate is treated and disposed of in precisely the same manner. It is handled by two classifiers, two thickeners, and two filters—identical with those just described—one of each of which, however, may also be used for nickel-copper concentrate, if required.

Vacuum at about 25 in. is furnished for the filters by five 31x12-in. vacuum pumps.

Although the surrounding terrain is level, compared with that of most mining districts, it is sufficiently rugged and uneven to provide several satisfactory sites for tailing disposal. The impounding dam first selected for this use has an area of approximately 80 acres, upon which about 1,000,000 tons of tailing can be stored. This will necessitate a dam approximately 40 ft. high and 1,000 ft. long, situated about 1,100 ft. from the concentrator. Such a dam is now being built up by deposition of mill tailing itself, the general method of tailing disposal closely following the practice at many other concentrators. All final mill tailing, after automatic sampling, is conducted to a central sump which is served by six 6-in. Wilfley sand pumps, the use of only one (and occasionally two) of which has yet proved necessary. The tailing, averaging about 20 per cent solids, is pumped through one or more of three

Dewatering equipment



12-in. wood-stave lines—each approximately 1,200 ft. long—against a total pumping head of about 55 ft., to the face of the tailing pond dam. Even with the plant treating 8,000 tons per day, any two of these lines should be of sufficient capacity, thus always leaving one for reserve. These lines have a fairly uniform, gentle slope from the dam face back to the mill, and may be readily drained.

The dam was started by building an earth retaining wall about 6 ft. high by horse-drawn slip scrapers and hand shoveling, and the construction of a wood trestle 10 ft. high and about 25 ft. from the face of the projected dam. Tailing pipe lines from the mill intersected this trestle midway, and the two outer ones, turned at opposite right angles, continued along the top of the trestle to serve the two halves into which the dam is divided. The center pipe line continues straight ahead across the dam. Holes 1½ in. in diameter, spaced on 5-ft. centers, were drilled in these trestle lines. These holes were placed about 45 deg. around the circle from the bottom of the pipe, and fitted with hollow cast-iron wear plugs of ¾-in. inside diameter.

In operation, tailing is alternately turned to each wing of the pipe lines, and short adjustable launders convey the tailing which escapes from the pipe holes to the face of the dam, the finer portion being carried further inward. The face of the dam is kept shaped, and a low outer retaining wall is thrown up by hand shoveling.

Two permanent chimneys, each with an adjustable weir intake, were constructed within the dam area previous to the first utilization of the tailing pond. From these, clear settled water flows through a submerged 16-in. wood-stave line back to a storage reservoir for subsequent use in the concentrator, this line passing through the sand retaining dam en route. Such arrangement permits the level of the impounded dam water to be regulated so that the proper proportion of returned water to original fresh water may be obtained.

Table III shows average screen analyses on some of the mill products.

Average analyses for iron, sulphur, and silica on the products shown in Table III gave the following results, in per cent:

	Iron	Sulphur	Silica
Flotation feed	33.25	19.80	23.10
Copper concentrate	36.85	32.20	4.15
Nickel-copper concentrate	37.05	25.55	14.60
Final mill tailing	19.70	4.95	44.25

The various reagents used during the last several weeks, and their average consumption in pounds per ton, are given in Table IV. Several combinations were employed for experimental purposes, the table, however, showing the average consumption of each reagent while being used.

Table IV—Reagent Consumption

Reagent	Pounds per Ton
No. 80 flotation oil	0.17
No. 15 Aerofloat	0.06
No. 25 Aerofloat	0.06
G.N.S. No. 5 pine oil	0.30
Sodium xanthate	0.22
Copper sulphate	0.40
Lime	1.60

With the complexity of pipe-line systems throughout the mill, some method of individual identifications appeared necessary, both as a safety measure and to prevent confusion. All pipe lines are painted, either in solid or banded colors, to designate their particular content, the scheme of colors used being based upon the code of the American Standards Association. Also, stencil legends are used in many places for additional clarity.

Despite the almost completely fireproof construction of all the buildings, high-pressure water pumps and adequate fire lines are provided.

Power comes from International Nickel's several power plants, all of which are situated within a radius of 30 miles from Copper Cliff. This power is generated and transported at 35,000 volts, 25 cycles, alternating current, and stepped down as required, the concentrator using 2,300, 550, and 100 volts at 25 cycles, distributed as necessitated for various requirements. A very small amount of direct current is also used.

Several control rooms, to which are led the power lines from the concentrator substation, are located in the crushing plant, screening plant, and the main concentrating building. The largest of these is 400 ft. long by 12 ft. wide, and in it are the controls for all motors with the exception of those used in the crushing and screening plant, the dewatering plant, and the roller mills, each of these having a separate control room. Through these control rooms, many operating units are interlocked, such as conveying systems, feeders, classifiers, and pumps. Although all machines are operated by adjacent individual push-button control, the roller mills, in addition, have been provided with rheostat control.

Table V shows the power distribution typical for present operations. Full-scale operation, and a more even load, should tend to decrease the per-ton consumption materially.

Table V—Typical Power Distribution for Mill

	Kw.-hr. per Ton	
Crushing and Screening Plant		
Total crushing	1.35	
Screening	0.37	
Conveying	0.76	
Lighting, dust control	0.85	3.33
Concentrating Plant		
Grinding	8.03	
Classification	0.37	
Flotation cell rotors	0.31	
Flotation cell air	0.90	
Flotation plant pumps	0.73	
Filter plant (except vacuum pumps)	0.66	
Vacuum pumps	0.93	
Water pumps	1.35	
Tailing disposal	0.51	
Conveying	1.14	
Lighting	0.48	
Sampling and miscellaneous	0.38	15.79
Grand total		19.12

Under full-scale operations, handling 8,000 tons per day, a total of approximately 200 men will be employed in concentrator operations, including dumping of the incoming ore and the delivery of the produced concentrates to the adjacent smelter. This implies the handling of 40 tons per man-shift.

At the time of this writing (the last week of September, 1930) but six weeks has elapsed since commencing mill operations—a period entirely insufficient to permit the possibility of securing and tabulating metallurgical information truly representative of the work which the plant is fully capable of performing. Operating results so far, however, have been most satisfactory and such as to warrant the belief that the excellent promises of the preliminary test work are realizable in our large-scale operations.

For the last few weeks the mill feed has averaged 3.40 per cent copper and 3.00 per cent nickel and the recoveries of these metals have averaged 97 and 93 per cent respectively, with an overall ratio of concentration of 2.04:1, results which are fully up to expectations.

Table III—Screen Analyses

Mesh	Mill Feed, Per Cent by Weight, This Mesh	Mill Feed, Per Cent by Weight, Cumulative	Flotation Feed, Per Cent by Weight, This Mesh	Flotation Feed, Per Cent by Weight, Cumulative
+ 6 mesh	0.33	0.33		
+ 8 mesh	8.08	8.41		
+ 10 mesh	13.35	21.76		
+ 14 mesh	10.40	32.16		
+ 20 mesh	8.98	41.14		
+ 28 mesh	6.44	47.58		
+ 35 mesh	7.07	54.65	0.48	0.48
+ 48 mesh	6.68	61.33	1.06	1.54
+ 65 mesh	6.80	68.13	1.86	3.40
+ 100 mesh	6.90	75.03	10.82	14.22
+ 150 mesh	3.30	78.33	10.05	24.27
+ 200 mesh	3.30	81.63	8.42	32.69
— 200 mesh	18.37	.....	67.31	.....
	100.00		100.00	

Mesh	Copper Concentrate, Per Cent by Weight, This Mesh	Copper Concentrate, Per Cent by Weight, Cumulative	Nickel-Copper Concentrate, Per Cent by Weight, This Mesh	Nickel-Copper Concentrate, Per Cent by Weight, Cumulative	Final Tailing, Per Cent by Weight, This Mesh	Final Tailing, Per Cent by Weight, Cumulative
+ 35 mesh	.....	.....	0.18	0.18	0.80	0.80
+ 48 mesh	0.38	0.38	0.36	0.54	1.90	2.70
+ 65 mesh	1.16	1.54	0.54	1.08	4.80	7.50
+ 100 mesh	1.02	2.56	5.92	7.00	23.89	31.39
+ 150 mesh	4.70	7.26	11.81	18.81	14.18	45.57
+ 200 mesh	6.87	14.13	8.33	27.14	21.28	66.85
— 200 mesh	85.87	.....	72.86	.....	33.15	.....
	100.00		100.00		100.00	

THE NEW 5,000-TON SMELTER

Donald MacAskill and R. M. Coleman

Manager, Mining and Smelting Division, and Metallurgist, respectively

THE metallurgy of the copper-nickel ores of the Sudbury district, which proved so troublesome when the district was first opened, has now been fairly well standardized and in general follows closely the practice of other American copper smelters up to the point of production of "white metal."

Up to June, 1930, the practice at Copper Cliff was briefly as follows: Coarse ore, plus-$\frac{7}{8}$ in., was first roasted in open heaps; mixed with reverts, coke, and flux when necessary; and smelted in blast furnaces to produce a matte containing approximately 25 per cent combined copper and nickel. The fine ore, minus-$\frac{7}{8}$ in., was ground dry in Krupp ball mills to pass a 10-mesh screen and was then roasted in multiple-hearth furnaces and smelted in a reverberatory to a matte containing 15 to 20 per cent copper and nickel. The blast-furnace and reverberatory-furnace mattes were then blown in basic-lined Peirce-Smith converters to 78 to 80 per cent metal, the so-called bessemer matte, which was shipped to the refinery.

At Coniston, where the Mond company's smelter was located, practice was similar, except that no heap roasting was done, all ore being either roasted on Dwight & Lloyd machines or charged green to the blast furnaces. Reverberatory-furnace smelting was not practised at Coniston, but in practically all other respects the practice at the two smelters was identical.

The main variation from the practice at other modern copper smelters has consisted in the adherence to blast-furnace smelting rather than reverberatory-furnace smelting. This has been partly because concentration was unnecessary and partly for the reason that cheap hydro-electric power has been available, so that the waste-heat power credit so important in Southwestern smelters was thereby wiped out.

With the development of the Frood mine it was apparent that part, if not all, of this ore should be concentrated. Thus, a much larger amount of fine material would be sent to the smelter, and the problem of treating it was given much study. If the existing blast-furnace plant at Copper Cliff was to be used, sintering of the concentrate would be necessary, and experimental work on a Dwight & Lloyd machine was carried out to determine the practicability of this method of treatment. The results of this work indicated that concentrate could be successfully sintered either calcined or green or mixed in any proportion, though if sintered green it was necessary to have a portion of the material in the form of coarse table concentrate to provide a more porous bed of material through which air might penetrate.

Sintering and blast-furnace smelting, however, was finally abandoned in favor of roasting in multiple-hearth furnaces and reverberatory-furnace smelting, as is the common practice elsewere. Costs promised to be lower even though the reverberatories received no credit for waste-heat steam.

The new smelter at Copper Cliff, therefore, consists of 30 ten-hearth Herreschoff roasting furnaces, five reverberatory furnaces, and eight Peirce-Smith type converters. The estimated capacity of this plant is roughly 5,000 tons of ore or concentrate per day. In addition, three of the eight old blast furnaces will be retained for smelting reverts, with which some coarse green ore will be mixed. The Coniston plant, too, has been retained, giving a total smelter capacity of about 8,000 tons of ore and concentrate per day, equal, with the mill, to handling about 13,000 tons of mine ore per day with all units operating at full capacity. With the grade of ore at present being produced, total smelter capacity is about 17,500 tons per month of combined copper and nickel.

In general design, the new smelter was the work of A. G. MacGregor, and the details were worked out by the International Nickel Company's staff. Several constructional features are discussed in Mr. Sheridan's article, which should be referred to in connection with the description to follow.

The general layout of the conveying system provides a flexible plan whereby material is carried in a straight line from one department to another, but is moved at right angles on conveyors for treatment in any one department. This allows of bypassing either mill or roasters with a minimum of difficulty. It also makes possible further expansion of mill or smelting facilities with comparative ease, as only an extension of the cross-conveying system is needed to serve added units.

The new smelter site is embraced within the yard of the old plant, to the north of the old converter building and to the west of the former roaster-reverberatory plant. It adjoins the new concentrator, on the south, from which concentrates are received by two 36-in. belt conveyors discharging into one of two other 36-in. belt conveyors which deliver into the roaster storage bins. These bins, immediately above the roasters, are of steel with slightly sloping sides. Each pocket has a capacity of 100 tons of ore or concentrate, and there are 30 in all, one for each roasting furnace. The ore or concentrate is removed from the hopper bottom of these bins by projecting arms attached to the central shaft of the

furnace. Subsidiary steel bins of 25 tons' capacity are provided between the larger bins. These smaller pockets are supplied from the same conveyor as supplies the larger bins, and are used for such materials as may be required to bypass the roaster, as these bins discharge through 12-in. pipes directly into the charging device on the reverberatory furnace.

Thirty Herreschoff furnaces, each with ten interior hearths and a drying hearth, constitute the roasting plant. Outside, the diameter of these furnaces is 21 ft. 6 in. and the height is 31 ft. 8 in. Their in-hearths have an area of 317 sq.ft. and the out-hearths, 310 sq.ft. The drop hole of each hearth takes up about 35 sq.ft.

The 9-in. walls and the hearths are of high-alumina fireclay brick set in refractory cement. In each furnace the central shaft, of cast iron, is 3 ft. 2 in. outside diameter, built up in sections. Two rabble arms for each roasting hearth are attached to the central shaft by a single steel pin, these arms being easily removable through the furnace doors. All rabble arms except those on the drying hearth, as well as the central shaft, are air-cooled. In addition to the openings in the central shaft for arms, two other openings are provided through which a portion of the air used for cooling the arms and shaft may be allowed to escape into the furnace to supply combustion air; otherwise it is conducted from the top of the central shaft to the outer air.

The shaft rests on a step bearing and is revolved by a spider geared to a 23:1 speed reducer driven by a 25-hp. variable-speed motor. A range of twelve speeds is available on the motor, and a two-speed step pulley gives an additional range of speeds. Variable-speed motor equipment is a special feature here and has proved to be of great value. At present the average speed of the furnaces is about 2 r.p.m., but this has not been standardized. A low limit of 0.4 r.p.m. is possible with the equipment.

A reduction of sulphur content from 28 to 16 per cent will probably be satisfactory practice, though at 2 r.p.m. it is possible to reduce the sulphur to 4 per cent, this being much too low to produce the desired grade of matte in the reverberatory furnaces. The immediate objective is to obtain a calcine of the desired grade, at the same time maintaining the maximum heat of the roaster on the lower hearths so that the calcined ore may be discharged into the reverberatory furnace as hot as possible.

In designing the roaster-reverberatory plant, the roasters were superimposed on the reverberatory furnaces, the object being to discharge the calcine into the reverberatory with minimum heat and dust losses and to minimize handling expense. The general arrangement is shown in Fig. 2.

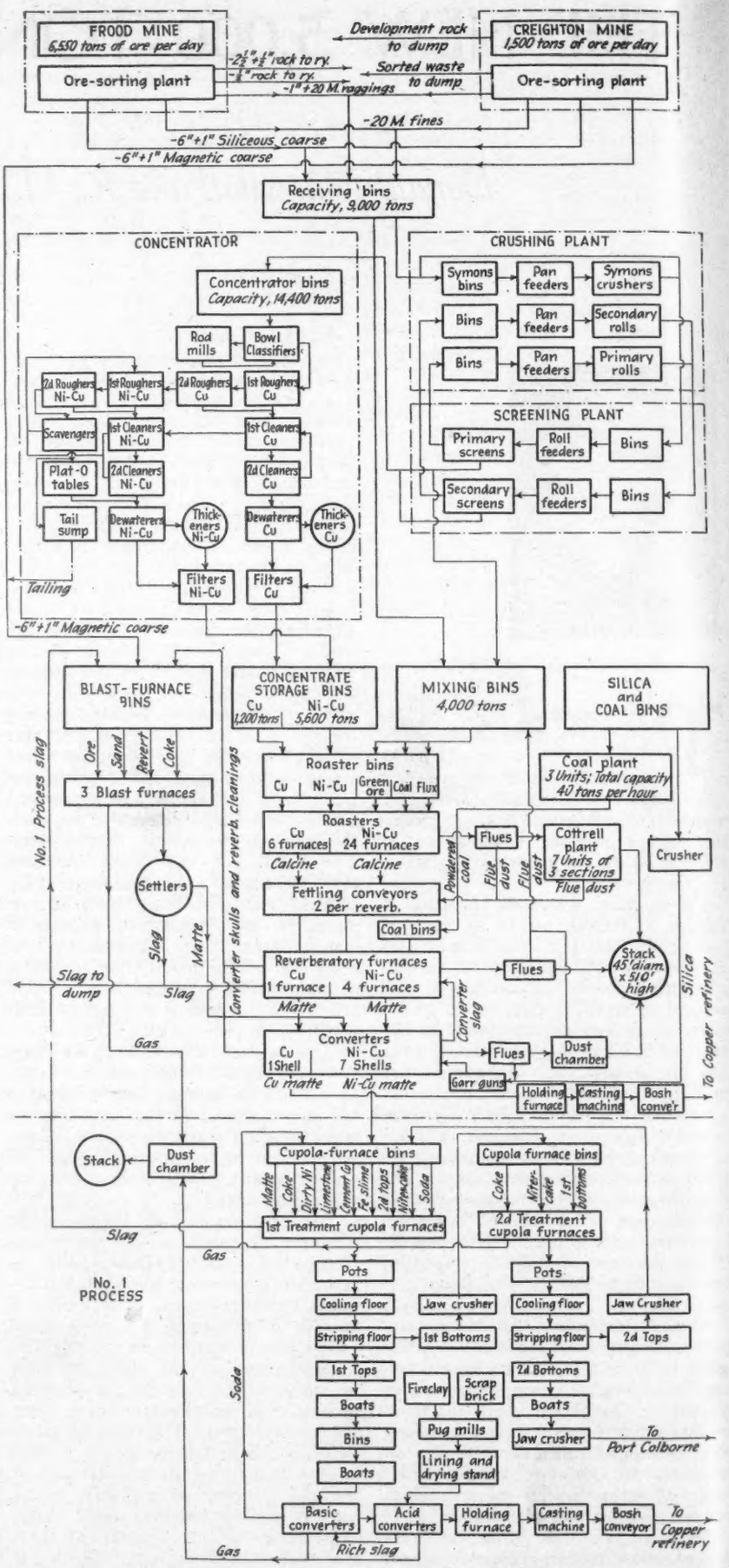


Fig. 1—Flow sheet, mines to refinery

The roasters are arranged in sets of three abreast, six furnaces to each reverberatory furnace. Under the center furnace are two 12½-ton steel bins lined with firebrick, one on each side of the furnace. These two bins form discharge pockets for the center furnace as well as for the outer furnace adjacent to it. In addition, the outer furnaces have each a discharge bin on the side remote from the center furnace. Each of two adjoining bins discharges into a 12-in. iron pipe, these pipes uniting and delivering into a third, which meets the discharge from the other two bins. The final conduit is a 12-in. iron pipe discharging into a 5-ton bin in the calcine conveyor housing above the reverberatory furnace. Calcine is delivered from the roaster through a short iron nipple, and the discharge from the roaster calcine bins is regulated by a gate in the hopper operated by a wheel which is actuated by a chain extending to the reverberatory charging platform.

The calcine conveyor—a drag chain with steel paddles, operating in a dustproof housing—runs the length of each side of each reverberatory furnace. Power is transmitted by a motor at the head end of the conveyor, through a shaft passing into the housing, which shaft operates a sprocket for driving the chain. The 6-in. charging pipes, spaced at 3-ft. intervals, enter the bottom of the conveyor housing and release the calcine into the furnace. The discharge through these pipes is governed by a hand-operated slide valve and is regulated by the appearance of the smelting charge as seen through an observation hole in the specially designed fettling pipe. Charging is done intermittently and the charge is carried to within about 20 ft. of the front (flue) end of the furnace.

All of the reverberatories are straight-arch furnaces, 114 ft. long by 27 ft. 9 in. wide, outside. Their end walls are 1 ft. 10½ in. thick. The arch is in 12-ft. sections with 1½-in. expansion joints between. The first four sections from the firing end of the roof are of 20-in. silica brick; the remainder of the roof is of 15-in. silica brick. An unusual feature of the roof construction is the use, on the 20-in. roof, of magnesite brick, which extends 4 ft. in from the skewback on both sides of the furnace, the remainder of the arch being of silica brick. The object of this magnesite insert is to prevent corrosion of the roof at these points, owing to the basic nature of the charge.

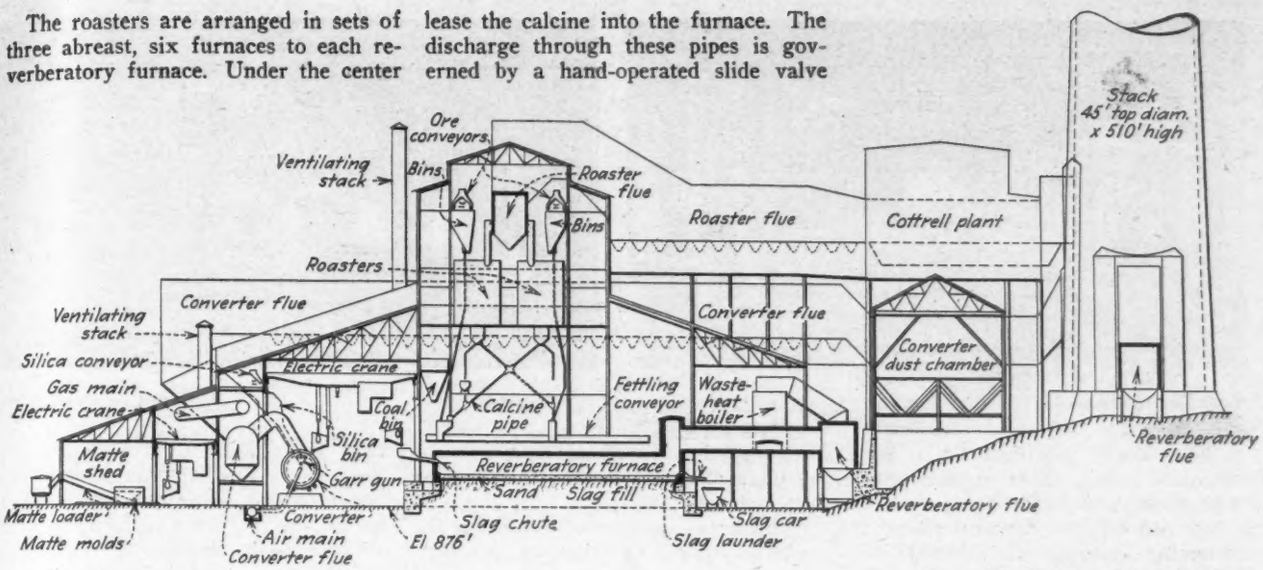


Fig. 2—Cross-section of smelter

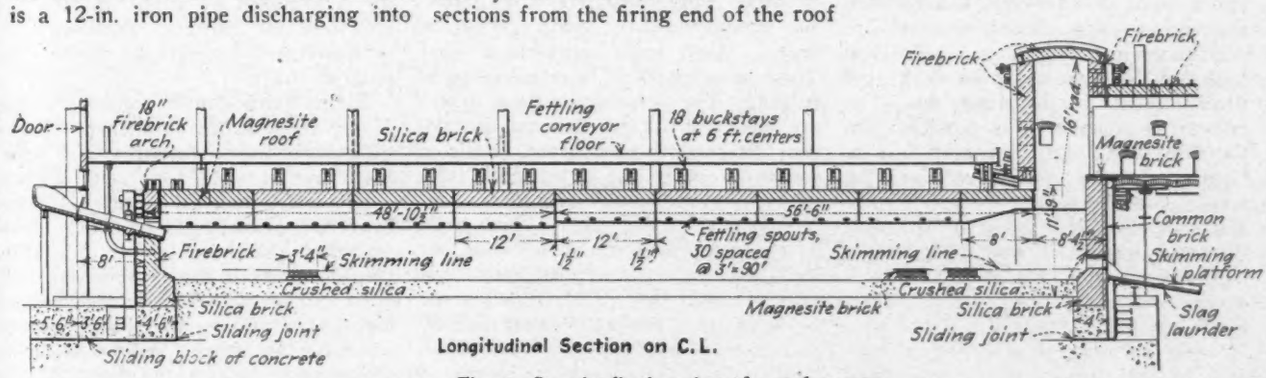


Fig. 4—Longitudinal section of reverberatory

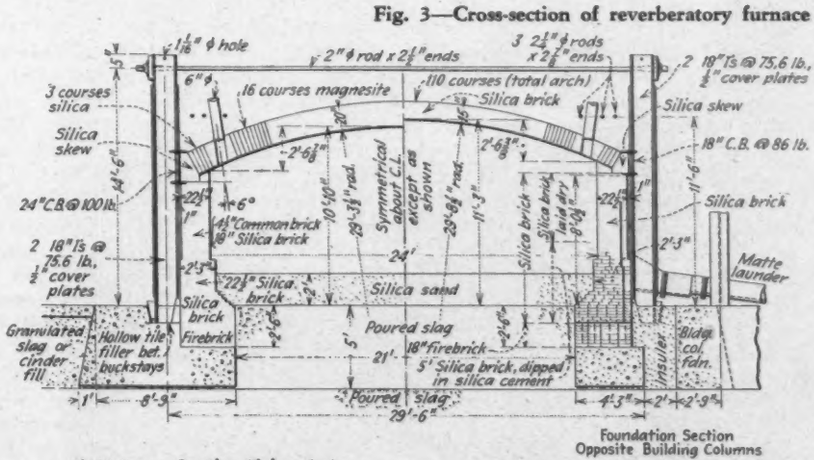
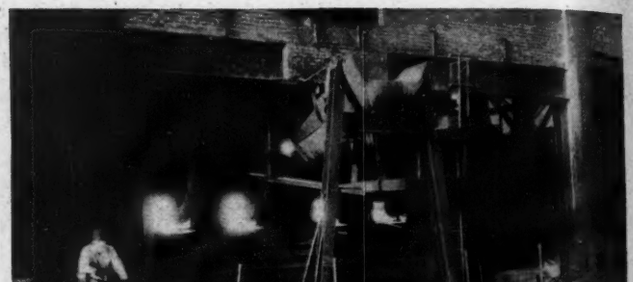


Fig. 3—Cross-section of reverberatory furnace

Bessemer matte molds

Photos courtesy "The Northern Miner"



Back end of reverberatory

Silica skews are used, set in longitudinal I-beams. Roof cramps on the flue cover a firebrick lining, and the front end of the furnace above the skimming plate is of firebrick with silica brick below. Double chrome tapping blocks 14x14x6 in. are used, surrounded by magnesite brick. Six tapping holes are provided for each furnace, three on each side. One of these is 17 ft. from the front end, the second is 6 ft. further back, and the third, which is for emergency only, is 19 ft. from the back end of the furnace.

The furnace bottom consists of 12 ft. of furnace slag poured against concrete retaining walls as described by Mr. Sheridan. On top of this is 24 in. of 98 per cent silica sand put in damp and tamped down every 4 in. When the furnace was started, a wood fire was maintained for about a week, low coal fire for two or three days, and finally a hot fire to sinter the silica bottom as completely as possible. On the third and fourth furnaces, a 2-in. layer of flue dust was spread over the sand. This flue dust smelted readily and combining with some of the sand formed a highly siliceous slag with a high fusion point, and no trouble was experienced from the bottom rising, following this procedure.

Converter slag is poured into the back of the furnace by the converter cranes, through sectional cast-iron launders. Reverberatory slag is skimmed as continuously as possible through water-cooled cast-iron launders into 20-ton steel ladles. Skimming is discontinued for five minutes after pouring converter slag into the furnace and for brief intervals between spotting the slag ladles. Matte is tapped through uncooled cast-iron launders into steel ladles for transfer to the converters.

Waste-heat boilers are provided on two of the five furnaces, but they are used only when steam is required for heating the various buildings within the smelter area.

Operations have not been conducted for a sufficient length of time to furnish reliable operating data. It is hoped, however, that a matte grade of approximately 25 per cent may be maintained, with a slag carrying 36 per cent silica.

Powdered coal is used for firing the reverberatories. Equipment for this part of the plant was built by Heyl & Patterson, of Pittsburgh, and has a capacity of 700 tons of coal per fourteen hours of operation. Coal, even though imported from West Virginia or Pennsylvania, as it is, is, nevertheless, more economical than oil. High-volatile clean slack coals containing 7 to 10 per cent ash are used. This coal is received in steel bins formerly used for ore for the old reverberatory plant, from which it is transferred by belt conveyors to a Jeffrey swing-hammer crusher and thence by belt conveyor to three single-shell Heyl & Patterson concurrent-flow rotary cylindrical dryers, fired with pulverized coal. These are each 7½ ft. in diameter by 50 ft. long. The burners for these dryers are electrically controlled by thermostats attached to each dryer. Helicoid conveyors carry the dried coal from the dryers to small bins over four Raymond six-roller mills. These mills have a rated capacity of 13½ tons per hour, but this output has been considerably exceeded. Coal is pulverized to 93 per cent minus-100 mesh and 80 per cent minus-200 mesh. The Raymond mills are air swept by means of Sturtevant blowers to cyclone collectors, which deliver the pulverized coal to closed cylindrical steel storage tanks. From the latter the coal is drawn to steel weighing tanks, where, after being weighed, it is aerated by air at 80-lb. pressure, and is then blown through a 5-in. pipe to 60-ton steel storage bins over the back end of the reverberatory furnace. The filling of these bins, and the control valves for switching from one to another, are all operated from a central point in the pulverized-coal building. One central vent is provided in the coal plant, discharging into a cyclone separator and thence into the smelter flue system.

From the storage bins, of which there are five, one to each reverberatory furnace, the coal is fed by Heyl & Patterson screw feeders driven from a line shaft by a 50-h.p. motor. The rate of feeding is controlled by a variable-speed reducer, and a tachometer on the line shaft indicates the rate of coal feed, checked by revolution counters on each of the coal feeders.

A vent in the top of the pulverized-coal storage bins is connected to the intake of the fans which supply primary air to the burners. These fans are rated at 10,000 cu.ft. per minute at 4½-in. water gage, and one is provided for each furnace. There are four fishtail type burners to each furnace, and any combination of these burners may be used at once. Each burner has a total maximum capacity of 3,600 lb. per hour of powdered coal, or 170 tons per day per reverberatory. Primary air is provided by a fan, to blow the coal into the furnace. Secondary air is introduced around the burners by induced draft.

Eight Peirce-Smith converters, 13x 35 ft., are installed parallel to the row of reverberatory furnaces and separated by an aisle for crane service. There are no unusual features of these converters except the movable hood described elsewhere by Mr. Sheridan. One or more of these converters will, it is expected, be used for blowing high-copper matte to blister copper, whereas the others will concentrate nickel-copper matte to about 80 per cent, casting at the white-metal stage.

Silica flux, sand, or low-grade siliceous mine rock is brought to steel bins above the converter flue by belt conveyors, and is fed as required into a hopper which feeds the Garr gun. The latter is installed on one end of the converter, and all the flux is charged through this gun by 12-lb. converter air. Each shell is provided with an automatic direct turn-down which operates whenever the air pressure falls below a certain mark.

There are 48 1½-in. tuyères on each converter, but, of these, the ten directly under the stack are not kept open, to minimize the amount of slag accretion on the hood. The tuyères are cast iron, of rectangular cross-section, and with a cylindrical hole through them. Two punchers are regularly used, but

three may be required to bring up the heat early in a blow on a high-grade matte. It is desirable to have the matte charged to the converter run about 25 per cent copper plus nickel.

Steel ladles are used for handling the matte to and from the converters (as well as the slag). They are of 185-cu.ft. capacity and are provided with removable cast-iron lips. They are handled by 50-ton cranes. All skulls are broken in a MacGregor skullbreaker of conventional design.

Behind the converters and separated from them by a hollow tile wall is a steel balloon flue, carrying converter gas to the main stack.

Nickel-copper converter matte is pulled over transfer tracks to the casting aisle, which is equipped with a 50-ton main hook and a 10-ton auxiliary hook crane. The matte is cast into sectional cast-iron molds on the floor of the building in slabs about 4 in. thick. These slabs, when cooled, are picked up by 10-ton electric traveling cranes and broken through an elevated grizzly into one of two pan conveyors, which, in turn, discharge the material into box cars for shipment to Port Colborne, Huntington, or the No. 1 Process bins at Copper Cliff.

The copper concentrates will be treated in a separate reverb and converter. The copper-converter matte will be charged into an oil-fired reverb-type holding furnace having a hearth of 12x32 ft. inside and a capacity of approximately 200 tons. Copper is to be cast into pigs for shipment to the Ontario Refinery at Copper Cliff, on a straight-line Allis-Chalmers casting machine. The copper pigs are discharged into a bosh tank and elevated to a shipping platform by a drag conveyor.

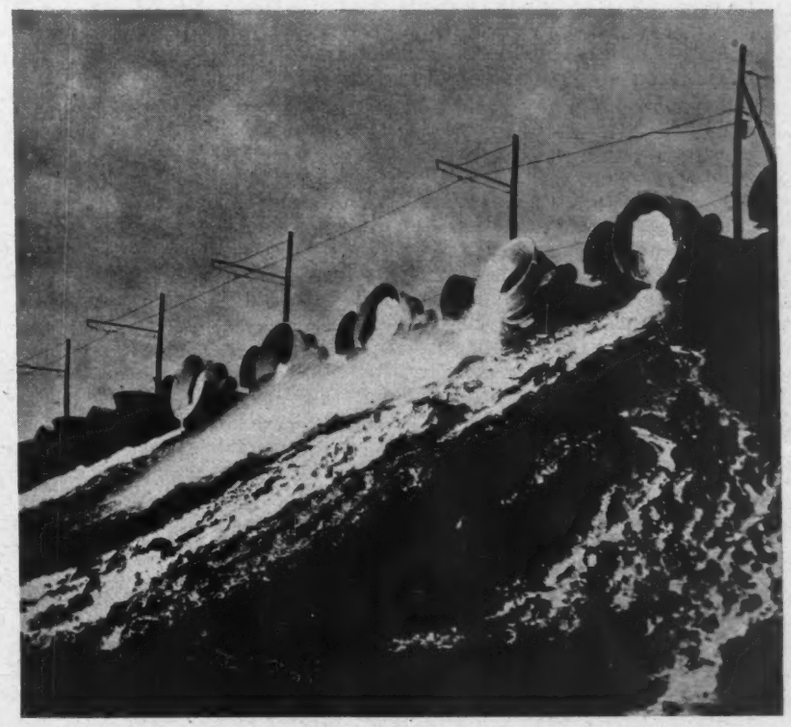
Converter air is furnished by turbo compressors driven by electric motors. There is one Rateau-Battu-Smoot blower with a capacity of 42,000 cu.ft. of free air per minute, compressed to 14 lb. In addition two Brown-Boveri units of 25,000 cu.ft. each, and one unit of 40,000 cu.ft., have recently been installed, and in reserve are two Allis-Chalmers piston-type machines of 20,000 cu.ft. capacity each. The total capacity of 14-lb. air is 172,000 cu.ft. per minute for both the basic converters and the No. 1 Process to be installed next year.

Gases from the roasters, reverberatory furnaces, and converters, with the exception of that portion of the converter gases delivered to the acid plant, are carried through separate flues to the main stack, which is 510 ft. high and 45 ft. 2 in. inside diameter at the top, with four openings in the base. This stack is built of hollow radial tile, burned from shale at Cooksville, Ont., and is the largest in the British Empire. It has a 6-in. lining of special Ohio acid-resisting brick, supported on corbels every 35 ft. in height. A tunnel projects under the stack, with clean-out gates for removing dust. The floor of the stack is inclined, making a V-hopper, lined with paving brick. Lightning protection consists of $\frac{7}{8}$-in. copper rods 7 ft. apart around the top. Four vertical leads extend to the ground, which are interconnected by horizontal bands of copper every 50 ft. All are lead covered. Four grounds are connected to the stack, consisting of copper plates buried in charcoal 6 ft. below the surface. The stack draft is 3 in. of water at 500 deg. F.

All flues are of brick except the converter flue, which is of steel. Dust from the converter flue system is returned to the converters with the flux, whereas dust from the settling chamber and reverberatory flues is transferred by dust-tight narrow-gage cars to broad-gage cars for delivery to the receiving bins.

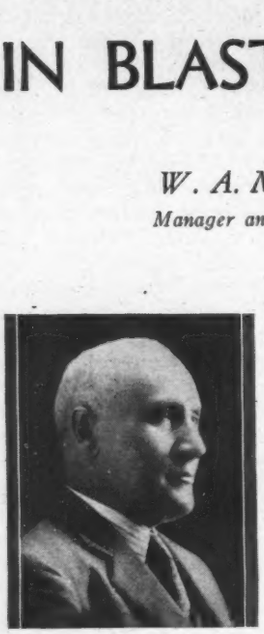
The greater part of the gases from two of the reverberatory furnaces may be bypassed through two 800-hp. waste-heat boilers. The remainder of the reverberatory-furnace gases, with the gases from the boilers, pass through flues direct to the stack. The gases from each roaster are delivered through two cast-iron uptakes, fitted with dampers, to a steel-hoppered brick and tile flue, 14x18 ft., above the hoppers. This flue extends the full length of the building and is connected at the center of the building by a cross flue, 20 ft. wide by 25 ft. high, leading to the Cottrell dust precipitation plant.

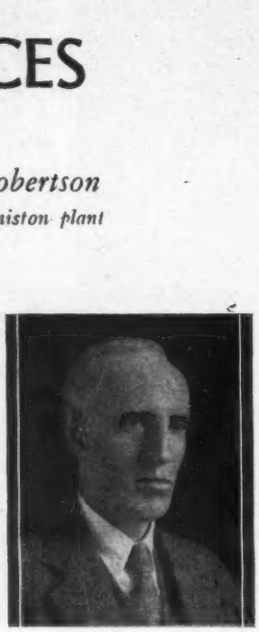
The Cottrell plant is designed to treat the gases from the 30 roasters, and its capacity is rated at 600,000 cu.ft. per minute, at 700 deg. F., with a dust recovery of 90 per cent. The treater consists of seven units, or flues, 12 ft. wide, 18 ft. deep, and 40 ft. long. Each unit comprises three sections, two of which are electrically connected and receive current from one rectifier, the third, or outlet section, receiving current from a separate rectifier. Each section contains nineteen grounded collecting electrode "rod" curtains and eighteen high-tension discharge electrode twisted-wire curtains. The collector electrodes are rapped by pneumatic hammers controlled by solenoid valves operated by push button. Precipitation current is supplied by 25-kva. transformers and rectifiers, two for each unit and one spare. Rectifiers are driven by 2-hp. synchronous induction motors. High-tension voltage is controlled between 40,000 and 60,000 volts. A special choke coil is connected in each of the rectifier leads and also where the high-tension lead enters the treater section, the purpose of these coils being to prevent interference, by the Cottrell plant operation, with radio broadcast reception. All openings giving access to high-tension equipment or electrodes are protected by automatic grounding switches to prevent any person from coming into accidental contact with live parts carrying high voltage. Tests have shown high dust-recovery efficiencies, up to 97 per cent of total solids, and 98 per cent total copper plus nickel.



SMELTING AT CONISTON IN BLAST FURNACES

W. A. MacDonnell and J. F. Robertson
Manager and Metallurgist, respectively, Coniston plant





CONSTRUCTION of the Coniston works was started by the Mond Nickel Company in 1911. The plant was designed to supersede the company's smelter at Victoria mines, a small unit that had been in operation since 1901. The old smelter, though well placed for treating the ore from Victoria mine, was on a limited site with inadequate railway connections to mines developed later. Coniston is near the southeastern end of the nickel basin at the intersection of the main line of the Canadian Pacific Railway with the Toronto branch of the Canadian National. Connection with the two railways, proximity to Garson mine, and suitable topography and water supply fixed the site. The smelter was blown in early in 1913 and has been in continuous operation ever since.

The most interesting technical operating point at Coniston has been the development of the sintering of copper-nickel fine ore for blast-furnace smelting. Toward the end of operation at Victoria Mines that plant was overloaded with fines. A roast yard was built at Coniston, and, as soon as convenient after the smelter was blown in, a two-unit Dwight-Lloyd sintering plant was added. Later, two more sintering units were built, and heap roasting was gradually eliminated. This plant turned all the fine ore and flue dust, as well as the small tonnage of concentrate made, into sinter for the blast furnaces, burning out about one-third of the contained sulphur. The resulting furnace matte carried only about 15 per cent of copper plus nickel, but the smelting of up to 65,000 tons per year of low-grade ore in the converters gave a credit which kept net converting cost from being excessive. Heap roasting was an isolated operation involving extra transportation cost, a leaching loss difficult to measure, and smoke-damage nuisance.

Tonnages increased, and the four-unit sintering plant became inadequate. Improvement was authorized, but was postponed until the union with International eliminated from the picture Mond reverberatory smelting of ore from the company's Frood Extension mine. Soon after the merger, the original four-unit sintering plant was replaced by one of six units, each 50 per cent larger in size. This plant is on a high, level site, in better relation to the blast furnaces than was the former site.

The new sintering plant is on flat ground behind, and on a level with, the site of the smelter bins. This permits material to come to the plant on a convenient branch from the tracks to the ore bins, and the sinter pockets in front of the machines can deliver into the regular furnace charging cars. The charge to the machines consists of about 7½ per cent of concentrate, 2½ per cent of flue dust, and the rest fine ore. All the ore sintered is minus about ¾ in. and much of it now has had the minus-10-mesh material screened out for the reverberatory furnaces at Copper Cliff. On such a charge the capacity of the sintering plant is about 1,350 tons per day. The charge contains about 20 per cent of sulphur and the sinter about 13.5 per cent.

Receiving bins in two rows and of about 3,000 tons' total capacity are discharged through nineteen belt feeders onto a central collecting belt which delivers through a small protecting grizzly onto the inclined belt leading to the sintering plant proper. There a distributing belt with tripper delivers into the machine feed bins. These feed through belt and reciprocating feeders onto the six 42x396-in. Dwight-Lloyd sintering machines. Fuel-oil ignition is used. Machine speed is 12 to 20 in. per minute and suction, given by fans conveniently placed on the machine floor close to the head end of the machines, is about 20 in. of water. A 6-in. layer is usually carried. A guillotine cuts into the charge before ignition to make the slabs of sinter break off more easily at the discharge end of the machines. The grate slots are herringbone and are cleaned with pneumatic tools by two men on the day shift.

Sinter from each machine drops into a hopper which discharges through an air-actuated sliding gate into a measuring pocket. This is emptied through an arc gate, also opened by air, into furnace charging trains. Minimum water-cooling to control dust is used. Hard, full-sized cakes of sinter are not desired, but the size can be controlled by the charge and the machine speed, and by the height of drop to the top of the contents of the receiving hopper. The sintering plant is of concrete, steel, and brick, with a roof of 2x4 lumber on edge, and is thoroughly well built throughout. Ample sintering capacity, the feeding of comparatively hot sinter, and minimum of handling secured for the sinter by the use of the present site have markedly improved blast-furnace results at Coniston.

The smelter bins, for crude lump ore, returns, limestone, coke, and converter flux, are of wood, in parts concrete lined, and are divided into sections by concrete walls. Their capacity is about 200,000 cu.ft. They discharge through overhead gates into charging cars holding 2½ tons of ore each, drawn over a steel charging trestle to the furnaces by electric locomotives.

Slag tracks, blast furnaces, converters, and matte-loading equipment are all housed in a building of steel and corrugated iron 150x405 ft.

The blast furnaces, four in number, are 50x240 in. at the tuyères, with settlers 20 ft. in diameter. The furnace jackets extend down only to the top of the crucibles, 24 in. deep, which are lined with chrome brick, as are the settlers. Breast jackets and spouts are of cast iron, water-cooled. Slag is removed in steel slag cars of 260 cu.ft. capacity. Matte is tapped into 10-ton ladles on the converter floor. The converter slag is returned to the furnace settlers.

Furnace matte contains about 20 per cent of copper plus nickel. A small amount of limestone is used as flux, the furnace slag being held at about 38 per cent silica. The blast pressure is 32 oz. at the blowers. Coke amounts to about 10 per cent on furnace materials when the furnaces are being driven for tonnage, but has averaged 8½

per cent on the charge, or a little less, for considerable periods. Pyritic smelting has been tried repeatedly, but the rock in the Sudbury ores softens with the heat to a pasty mass which will neither stand up in the furnace nor run out of it. For a recent six-month period, tonnage of charge, ex coke, per square foot of area at the tuyères, averaged 8.25 per 24 hours in blast, with high months averaging 9.0 tons. During the same six months the blast furnaces smelted 63,000 tons of ore and 3,000 tons of concentrate per month, and the converters 2,500 tons, a total of 68,500 tons; and the mill concentrated 9,500 tons. This gives a total processed of 75,000 tons of ore per month, or 2,500 tons per day.

Five 13x30-ft. Peirce-Smith converters are installed, served by two electric cranes of 60-ft. span each, with two main hoists and one centrally placed auxiliary hoist. The converters are fluxed with sand and a small tonnage of fine crude ore to give a slag averaging about 25 per cent silica. Blast pressure is about 12 lb. at the blowers, rather low for 13-ft. converters, the original turbine blowing equipment having been purchased for 10x26-ft. shells which have since been replaced. The matte is blown to the white-metal stage containing about 79 per cent of copper plus nickel and a few tenths of a per cent of iron. It is chilled in cast-iron molds, broken over a rail grizzly, and shipped to the refinery. A part of the converter gas goes to a contact acid plant built by the Mond company in 1925 and now operated by Canadian Industries, Limited.

Hydro-electric power comes from company plants, plus a small amount purchased from the Ontario Hydro Electric Commission. This division of the source has many times proved convenient and valuable, especially as the line to the nearest Hydro plant is a short one.

The blowing equipment now in use is mainly turbine, both as regards furnace air and converter air, Rateau-Battu-Smoot machines being used. An electric- and gasoline-driven fire pump and an extensive works fire-fighting system has recently been installed. Shops built by the Mond company for mine as well as for smelter are adequate for plant maintenance and repair. The plant has, too, a company village built when Coniston was the Canadian headquarters of the Mond.

A blast-furnace plant without reverberatories, this may easily be the last large-tonnage smelter of its type to operate. Comparatively rich lump ores, self-fluxing or nearly so, and the overcoming of both the fines problem and the roasting problem by the use of Dwight-Lloyd sintering, have kept it a low-cost plant. Also, the cheap power available would have eliminated the credit for waste heat which is an important factor at many reverberatory smelters.

ACID AND NITER-CAKE PLANTS OF C.I.L.

— J. M. Malcolm
Chemical Development Department

PRODUCTION of sulphuric acid and niter cake in a dual plant, such as that recently put in operation by Canadian Industries, Limited, at Copper Cliff, resulted from (a) the desire to conserve the useful components of the nickel smelter fumes and (b) International Nickel's need for an adequate and constantly available supply of niter cake, or sodium acid sulphate. Niter cake is an essential material in the separation of copper and nickel by the Orford process, and, as a byproduct in the old processes of making nitric acid and hydrochloric acid it was cheap and plentiful. The introduction of the ammonia oxidation process for making nitric acid, and of synthetic hydrochloric acid, have, however, to a large extent dried up the sources of supply of byproduct niter cake.

Projected centralization at Copper Cliff of International Nickel's metallurgical operations—in the ultimate transference of the first step of refining at the company's Port Colborne plant to Copper Cliff—was a further factor in making desirable the installation of a dual plant at the smelter.

Production of sulphuric acid in the Sudbury district from smelter fumes is not a new departure, the Mond Nickel Company having commenced manufacture at Coniston in 1925. This Coniston sulphuric acid plant was later taken over by Canadian Industries, Limited. Useful experience gained in the operation of the Coniston plant, combined with the embodiment of all the latest improvements that diligent research has brought forth, has resulted in the Copper Cliff sulphuric acid plant, which presents the most up-to-date example of chemical engineering of its kind in existence.

The acid plant is about 1,000 ft. from the new smelter and is housed in a structure 216 ft. long, 115 ft. wide, and 75 ft. high at its highest point. It embraces three separate units, each having a capacity of 50 tons per day, with space for a fourth. The building itself can easily be extended to twice its present size.

The familiar contact process is used. Sulphur dioxide obtained from the converters at the smelter is led through a large steel flue to the acid plant. There it is cleaned of dust by scrubbing towers, after which it passes into Cottrell pipe-precipitator units to remove the final traces of mist and other impurities. Following this process, the gas is thoroughly dried by drying towers and is passed through the heat exchangers into the converters, where, by a suitable catalytic agent, it is converted into sulphur trioxide. This sulphur trioxide gas is then led into an absorption tower, where, by combination with a mixture of sulphuric acid and water, the sulphuric acid content of the gas is finally absorbed. After cooling and mixing, the finished sulphuric acid of desired strength is pumped to four large steel storage tanks, each of 1,000 tons' capacity, outside the building.

Sodium sulphate is loaded into the storehouse from freight cars through a bucket elevator and belt-conveyor system. It is reclaimed with a motor-driven drag scraper which feeds another bucket elevator and belt-conveyor system, which, in turn, fills the storage bins in the niter-cake building. Here are housed nine niter-cake units, each consisting of a feeder, mixer, oil-fired retort, and a cooling conveyor, with a total capacity of 225 tons of niter cake a day.

The sodium sulphate and sulphuric acid are fed into the mixer and from there into the retort where the chemical reaction takes place. From the retort, the hot fluid niter cake discharges at a rate of 120 ft. per hour into a series of pans attached to a moving chain. Cooling water is passed under the pans of the conveyor. The slow conveyor finally discharges into a second conveyor at right angles and moving at such a rate as to take care of the discharge from each of the nine units. The pans are shaped so that they form a cake about 2 ft. long by 4 in. wide, easily broken into three parts during the discharge because the pan itself has two "V" shaped divisions in it. A hammer strikes each pan as it is turning on the cool end of the conveyor and the pans are automatically sprayed with oil so that the cakes will drop out readily. The second conveyor carries the niter cake up an inclined passage into an elevated bin, from which the finished product is discharged by gravity into freight cars.

Thus has been put into operation the first plant designed and constructed for the special production of niter cake as a direct product. C.I.L. made a capital outlay of $1,500,000 in installing the dual plant. Fraser-Brace Engineering Company acted as general contractors for the work.

ELECTRIC POWER GENERATION AND DISTRIBUTION

—*W. E. Gillespie*
Electrical Superintendent

POWER is supplied to the mines and smelters from two hydro-electric systems known as the Huronian and the Lorne Power companies, both subsidiaries of the International Nickel Company of Canada, Limited. Huronian Power Company has three plants at High Falls, on the Spanish River, and connected to the C.P.R. at Turbine, 26 miles west of Copper Cliff, by 4 miles of company-owned track. Power is delivered to the Copper Cliff smelter, Frood mine, Creighton mine, and Ontario copper refinery at 30,000 volts, three-phase, 25 cycles.

The natural flow of the river would not always be sufficient to generate the required power, so water storage has been developed on the upper reaches of the Spanish. On several large lakes regulating and conservation dams have been built, some of these being of concrete and steel. This storage, when filled, holds approximately 450 square-mile-feet. The total watershed area is about 2,500 square miles, and it is estimated that an average flow of 1,800 sec.-ft. can be maintained throughout the year. During the spring floods the flow in the river has been as high as 25,000 sec.-ft.

Big Eddy dam, about half a mile above High Falls, was started during July, 1918, and completed about December, 1920. The dam is 1,175 ft. long, with a maximum height of 146 ft. It contains 88,000 cu.yd. of concrete and has eighteen sluices 17 ft. long by 8 ft. high, with one log sluice 8 ft. wide. This dam was built between rock bluffs, has a rock foundation throughout, and creates a lake 25 miles long, storing 380 square-mile-feet.

Power plants 1 and 2 are at High Falls. The river at this point is divided into two channels by an island. Power house No. 1, which was built during 1905, and power house No. 2, built during 1917, are both on the north side of the island. The concrete dam across the south channel is 350 ft. long and has three log sluices. Power plant No. 3 is at Big Eddy dam. It was built during 1928 and put in operation in February, 1929.

Power House No. 1 is a steel, brick, and concrete structure, connected with the forebay bulkhead by four 9-ft. steel penstocks and one 4-ft. penstock of similar material, each 250 ft. long. Motor-operated headgates are provided, with the operating mechanism in a gate house. This station has four horizontal double-runner turbines, 3,550 hp. each, which operate at 375 r.p.m. under an average head of 85 ft. The generators are 2,000 kva., 2,400 volts, three-phase, 25 cycles. There are two 200-kw. exciters, turbine-driven, connected to one 4-ft. steel penstock, one exciter having sufficient capacity for the entire plant. Each of the six banks of transformers consists of three 667-kva., single-phase, 2,600- to 34,000-volts, 25-cycle, water-cooled transformers, in concrete cells closed in by steel doors.

Power House No. 2 has one 7,500-hp. vertical single-runner turbine, connected with the forebay bulkhead by one 13-ft. steel penstock 400 ft. long, operating under an average head of 85 ft. at 187½ r.p.m. Its headgate is inclosed and is motor-operated. The governor is an I. P. Morris double floating lever type. In this power house the generator is rated at 5,555 kva., 2,400 volts.

When Big Eddy dam was built, penstock openings were inserted with the intention of building a power house here later. This power house is of steel, brick, and concrete, and is connected with the dam by three 12½-ft. steel penstocks 200 ft. long.

There are three vertical, single-runner Francis-type 9,400-hp. water wheels, which operate at 187½ r.p.m. under an average head of 90 ft. The generators are 8,000 kva., three-phase, 25 cycles, 90 per cent power factor, 6,600 volts, each complete with upper and lower guide bearings, Kingsbury thrust bearing, and a 90-kw. 250-volt direct-connected shunt-wound exciter.

Of the switching equipment the high-tension circuit breakers are Type G.A.-3, three-pole single throw, 600 amp., 66,000 volts, indoor electrically operated, and have a rupturing capacity of 250,000 kva. at 60,000 volts. The low-tension circuit breakers are Type B-26, 1,200 amp. 7,500 volts, electrically operated, and have a rupturing capacity of 150,000 kva. at 7,500 volts.

There are two transformer banks, each consisting of three water-cooled transformers, 2,670 kva., 6,600 volts low tension, 35,000 volts high tension, 25 cycles, single-phase. One 2,670-kva. transformer is kept as a spare unit. For station service there are three transformers, 200 kva., 6,600 volts high-tension to 550 volts low-tension, single-phase.

The main transmission line, built in 1905, is 30 miles long to the substation at Copper Cliff. It consists of two circuits of three No. 4-0 seven-strand hard-drawn copper cables, arranged with equilateral triangle 4-ft. spacing. The wires are supported on an H-frame made with wood poles, with common crossarms, placed about 150 ft. apart.

The Creighton mine branch connects with the main line at the second sectionalizing point, through gang-operated Horngap switches, and is a single circuit of No. 4 copper about 4 miles long. The Frood mine line was built during 1912, and is 5 miles long. It consists of three No. 1 hard-drawn bare copper conductors, supported on steel poles spaced 150 ft. apart. This branch connects to the main line through a G.A.-3 oil circuit breaker and disconnecting switches located in the main substation at Copper Cliff. The transmission line to the Ontario refinery was built during 1929 and is 1 mile long. It consists of three No. 1 conductors supported on wood poles, and also connects to the main line through a G.A.-3 oil circuit breaker and disconnecting switches.

Copper Cliff substation is a brick and concrete structure built during 1920. It contains two transformer banks, of 5,000 kva. each. Each bank consists of three single-phase 1,665-kva., 30,000-volt primary, 2,300-volt secondary, water-cooled transformers in fireproof compartments.

Before the new plant was built all power requirements for the smelter were taken care of by this substation. At present power is supplied to converter blowers, furnace blowers, 100-lb. air compressors, cranes, pumping, and lighting. Power is also supplied to the standard-gage electric railway through two 1,000-kw. 600-volt rotary converters.

To supply power to the new mill, crushing and screening plant, and reverb-roaster building, a new fireproof substation was built during 1929, centrally located. The incoming 30,000-volt line from the main Copper Cliff substation supplies power to four 2,000-kva., 30,000- to 2,300-volt transformer banks and one 3,600-kva., 30,000- to 575-volt transformer bank through G.A. breakers and disconnecting switches. These transformers are water-cooled.

Frood mine substation was built during 1928; it is a fireproof structure, attached to the hoist and compressor building. The incoming 30,000-volt line, controlled from the Copper Cliff substation, supplies power to one 5,000-kva. transformer bank, 30,000 to 2,300 volts, and one 825-kva. bank, 30,000 to 575 volts. A 1,000-kw. rotary converter, a duplicate of the converters at Copper Cliff, supplies power to the electric railway connecting Frood mine and Copper Cliff.

The Creighton mine substation is a fireproof building built during 1913 and is about 200 ft. from the compressor and hoist room. There are two 825-kva. transformer banks, 30,000 to 575 volts. These are shell-type water-cooled transformers, and have been in service since 1912 without repairs. The 30,000- to 2,300-volt transformers are water-cooled and of 833 kva. each.

Lorne Power Company was originally a subsidiary of Mond Nickel Company before the merger and supplied power to the mines at Levack, Garson, Frood Extension, and to the smelter at Coniston. This system transmits power at 44,000 volts, three-phase, 60 cycles, from two hydro-electric plants, the Nairn Falls plant and the Wabageshik plant.

The Nairn Falls plant is on the Spanish River about 7 miles below the Huronian company's plants and receives the benefit of the last-named company's water conservation and regulation. This plant was built in 1915, and operates under an average head of 32 ft. The river is divided at this point, by a rocky island, into two natural channels. A dam, 100 ft. long, is built across the north channel and has six waste sluices and a log sluice, each 10 ft. wide. The power station is built across the south channel and is of steel and hollow tile construction.

Power is transmitted by three single-runner vertical-shaft turbines in concrete spiral casings with concrete draft tubes. Motor-operated headgates are provided. Two of the turbines are rated 2,250 hp. and the third is of 2,500 hp., at 100 r.p.m. Two of the generators are 1,500 kva., 2,200 volts, three-phase, 60 cycles; the third generator is rated 1,875 kva.

The Wabageshik plant, on the Vermilion River about 4 miles south of Nairn Center, was built in 1908. Above this point the river has a drainage area of approximately 1,750 square miles. The concrete dam, which is about 700 ft. long, has ten waste sluices and one log sluice, each 10 ft. wide. Two motor-operated headgates admit water to the two 8-ft. steel penstocks which are 380 ft. long.

The two horizontal twin turbines operate under a head of 70 ft. No. 1 unit is rated 3,200 hp. at 300 r.p.m., its generator being 1,500 kva. No. 2 turbine, recently installed, is rated 3,000 hp. at 360 r.p.m. and is connected to a generator of 2,675 kva.

Approximately 85 miles of 44,000-volt wood-pole single-circuit transmission line supplies power to the Levack and Garson mines and to the Coniston smelter. The lines from Nairn Falls and Wabageshik come together at Crean Hill, from which point separate lines run to Levack and Coniston. A switching structure is placed at this point with gang-operated Horngap switches for line sectionalizing. Switches for this purpose are also located at Creighton, Frood, and Garson.

At Garson mine a new fireproof building was erected in 1929 about 50 ft. from the compressor building. It contains three 500-kva. self-cooled transformers, 44,000 to 550 volts, with a G.A.-2 oil circuit breaker.

The Coniston smelter receives its power supply from two separate sources, the Lorne Power Company and the Wahnapitae plants of the Hydro-Electric Power Commission, from which a block of 4,100 hp. is purchased. For the Lorne Power supply there is a bank of three water-cooled, single-phase, 1,500-kva., 44,000- to 550-volt transformers with a G.A.-2 oil circuit breaker. The Wahnapitae power is received at 22,000 volts and is transformed to 550 volts by three 1,500-kva. single-phase water-cooled transformers.

The important equipment at the various properties described in this article was furnished by the following companies:

English Electric Company of Canada, Ltd.: Transformers in power house No. 1, No. 3, and Wabageshik; Copper Cliff, new mill, Frood mine, Garson mine, and Coniston substations; 30,000- to 2,300-volt transformers in Creighton mine substation; and 750-kva. bank of transformers at Levack mine substation.

Canadian Westinghouse Company, Ltd.: High-tension switching equipment and relay protection in power house No. 1; generator in power house No. 2; generators and switching equipment in power house No. 3; Type G.A.-3, G.A.-2, B-2, B-16, B-20, and Type-E oil circuit breakers at several plants; and 30,000- to 575-volt transformers installed at the Creighton mine substation.

Canadian General Electric Company, Ltd.: Rotary converters in Copper Cliff substation; 1,875-kva. generator and switching equipment in Nairn Falls plant; generator at Wabageshik plant; and 1,500-kva. bank of transformers at Levack mine substation.

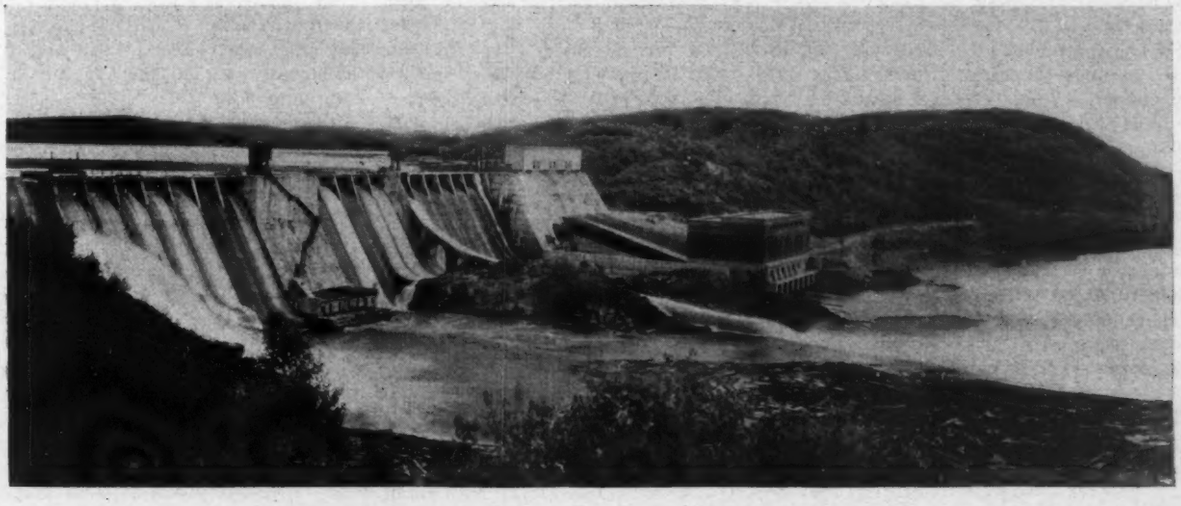
Canadian Allis-Chalmers, Ltd.: Turbines, two generators, and transformers in Nairn Falls plant, and turbines in Wabageshik plant.

Crocker-Wheeler Company: Generators in power house No. 1.

Dominion Engineering Works, Ltd.: I. P. Morris turbines in power houses Nos. 1 and 2; Francis-type water wheels in power house No. 3; also butterfly valves between each penstock and wheel case.

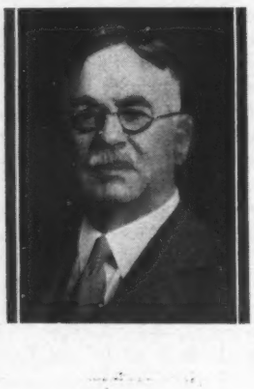
S. Morgan Smith Inglis Company: No. 2 turbine at Wabageshik.

The High Falls plant



REFINING NICKEL-COPPER MATTE AT PORT COLBORNE

—*R. L. Peek*
Consulting Metallurgist



IN OCTOBER, 1916, on a level site of about 360 acres at Port Colborne, Ont., the erection of what has grown to be by far the largest nickel refinery in the world was begun. The town is on the north shore of Lake Erie about 20 miles west of Buffalo, and the site has certain important advantages. It is favorably situated on lines of the Canadian National Railways, over which the Canadian Pacific has running rights for freight traffic, and is on the shortest route between the point of origin of the metals at Copper Cliff and the principal consuming centers in the United States, as well as shipping points for places abroad. Its proximity to the great electric generating stations at Niagara Falls is increasingly important, and various materials such as coke, coal, and fuel oil that are required are assembled here cheaper perhaps than in any other place in Canada.

To describe the plant it is convenient to trace the course of the metals through the refining process, and thus to describe concurrently both plant and operations therein.

Copper and nickel for refining are received as matte averaging about 42 per cent copper, 37 per cent nickel, and 20 per cent sulphur. In addition, small amounts of iron are present as well as gold, silver, and platinum-group metals.

All matte is shipped in bulk in box cars, and upon arrival is unloaded into large concrete bins situated on the east side of the building which houses the cupola furnaces and converters. These bins are constructed so that ordinary railway equipment may be run upon them over a ramp having a slope of 3½ per cent. Adjacent to the matte bins, and of the same construction, are bins for coke and niter cake.

The initial so-called "tops-and-bottoms" process comprises smelting the matte with niter cake and coke, giving a molten product containing sulphides of copper, nickel, and sodium as well as some slag from the coke ash. Next the molten sulphides flow into pots, where, owing to the unlimited solubility of copper sulphide in molten sodium sulphide and to the lesser solubility of nickel sulphide in the mixture, two layers result, the upper one, called "tops," of copper and sodium sulphide, and the lower one, or "bottoms," of nickel sulphide. The separation is not perfect; some nickel sulphide is dissolved in the copper-sodium tops and some copper and sodium sulphide are found in the nickel-sulphide bottoms.

The reason for using niter cake instead of the normal sodium sulphate (salt cake) is that the matte has not sufficient sulphur to combine with all the nickel and copper as Ni_3S_2 and Cu_2S, respectively: a part of the metals occur as a metallic alloy dissolved in the sulphides.

In matte containing, say, 39 per cent each of copper and nickel, 24 lb. sulphur per 100 lb. matte is required to react with all the metals. As the matte has only 20.5 lb. sulphur, about 3.5 lb. must be provided from other sources. The source employed is the sulphur contained in niter cake in excess of that required to form the normal sodium sulphate. In 39-39 matte, about 32 lb. of niter cake is thus required to meet requirements. In practice, larger amounts must be used, as volatilization takes a heavy toll of the niter cake charged.

To make two products, one high in copper for the converters and the other low in copper and high in nickel, two smeltings are employed. In the first treatment the bessemer matte is smelted with the "tops" resulting from the second treatment, and various reverts such as slag from second treatment and converters, and wet-house slimes. There result "first tops" containing about 46 per cent copper and 4 per cent nickel, and "first bottoms" with about 11 per cent copper and 64 per cent nickel.

The second smelting is performed on the "first bottoms," and here the niter cake and sodium sulphate recovered from the basic converters are used. Enough coke is used to reduce the sulphates to sulphides and smelt the charge. There result "second tops," with about 14 per cent copper and 20 per cent nickel, and "second bottoms," with about 1.5 per cent copper and 72 per cent nickel. It is desirable to have substantially all of the nickel present as sulphide to facilitate the subsequent operations.

Furnace charges are prepared on the ground floor and are raised to the feed floor level in iron buckets by 5-ton bridge cranes.

The five furnaces are each water-jacketed, with a hearth 5 ft. 10 in. x 12 ft., and 3 ft. 8 in. from center of tuyères to top of jackets. A brick shaft above the jackets makes the height from center of tuyères to sill of charge door 18 ft. There are 10 tuyères, 4 in. diameter on each side. From the hood a brick flue 5x5 ft. connects to a header 7x8 ft., which in turn connects with one of the main flues. One of these is 7 ft. 3 in. x 10 ft. x 200 ft. long and the other 8x10x265 ft. long. Both terminate at the base of the reinforced-concrete stack, which is 12 ft. in diameter at the top and 350 ft. high.

Owing to the corrosive character of the sodium sulphide, it has not been found practicable to use a trapped spout. The molten products flow continuously into large cast-iron pots having an elliptical cross-section and holding about 12,000 lb. of mixed sulphides. The pots are about 63x74 in. at the top and 42 in. deep, have a capacity of 66 cu.ft., and weigh empty about 10,000 lb. They are handled by 10-ton cranes which serve the furnaces and cooling and stripping floor. When a pot is filled it is carried to the cooling floor, where it stands from 36 to 40 hours, in which time its contents have stratified as tops and bottoms, and have frozen and cooled sufficiently to be dumped out on the stripping floor.

Ordinarily, the stripping of the nickel bottoms from the copper tops is accomplished by striking the material a few blows with a sledge, and shoveling the broken-up material into steel boats or iron pots. With the first smelting products the bottoms are taken to a 24x48-in. jaw crusher set with an 8-in. opening, where they are crushed to make acceptable feed for the second smelting. The first tops are taken by a crane to one of the basic converters. Next, the crushed first bottoms are smelted with niter cake and sodium sulphate recovered in the basic converters. The second smelting products flow into iron

pots and after cooling and stripping, as with the first smelting products, the second tops are sent to the first treatment furnace and the second bottoms are loaded on narrow-gage cars to be taken to the wet-process building.

Located midway between cupolas and converters are two slag furnaces with hearths 10x28 ft. and which are fired with pulverized coal. These furnaces are connected by underground flues to separate 48-in. brick-lined steel stacks 110 ft. high. The slag from these furnaces is granulated in water and raised by a bucket elevator to a storage bin. From there it is loaded by gravity chute into railroad cars for transportation to the slag dump.

To return to the first tops: these are dumped by the crane into one of the three basic-lined converters. Two of these are of the cylindrical type, 10 ft. diameter by 20 ft. long; the third is of the Great Falls type, 12 ft. diameter. The cylindrical shells have 10 tuyères, 1¼ in. diameter; the Great Falls shell has 18 1¼-in. tuyères. Electric power is used for turning the converters, the controls being adjacent to the shells. The usual magnesite linings are used. Blast is supplied from the power house at 15-lb. pressure.

In the converters substantially all the sodium sulphide is oxidized to sulphate wherein neither copper nor nickel sulphides are soluble: hence the copper sulphide settles to the bottom of the converter and the sodium sulphate floating on top may be poured off, to be returned to the second-treatment furnace.

The copper sulphide, with small amounts of nickel sulphide, is transferred in iron ladles by the cranes to the acid-lined converters, of which five are usually in operation. The iron shells of these are 7 ft. diameter by 10 ft. 6 in. long and are made in two parts to facilitate lining operations. There is also one large acid converter 96x150 in. with fourteen tuyères 1¼ in. in diameter. They are lined with a mixture of cheap fireclay, ground brick, or other suitable available material. Owing to the absence of iron in the copper sulphide, and the unavoidable presence of some sodium salts and nickel sulphide, it is impracticable to use basic linings for blowing to blister copper; hence the use of the acid-lined converters. Each shell has ten tuyères, 1¼ in. diameter, and is supplied with air at 15 lb. per square inch. To insure the slagging of most of the nickel, the copper is overblown, so that, as poured from the converter, it is saturated with cuprous oxide.

Heavy 50-ton cranes are provided for moving the acid shells from the blowing stands to the lining department. Here the lining is prepared by grinding and mixing the materials in two 7-ft. Chilian mills having rollers 55 in. diameter by 12 in. wide, after which it is rammed with air rammers around a steel form placed in the shell. The upper and lower part of the shell are lined separately, assembled, dried by a wood fire, and returned to the blowing stands. To keep five blowing stands supplied, fifteen shells are required. Each lining suffices for the production of about 120,000 lb. of copper.

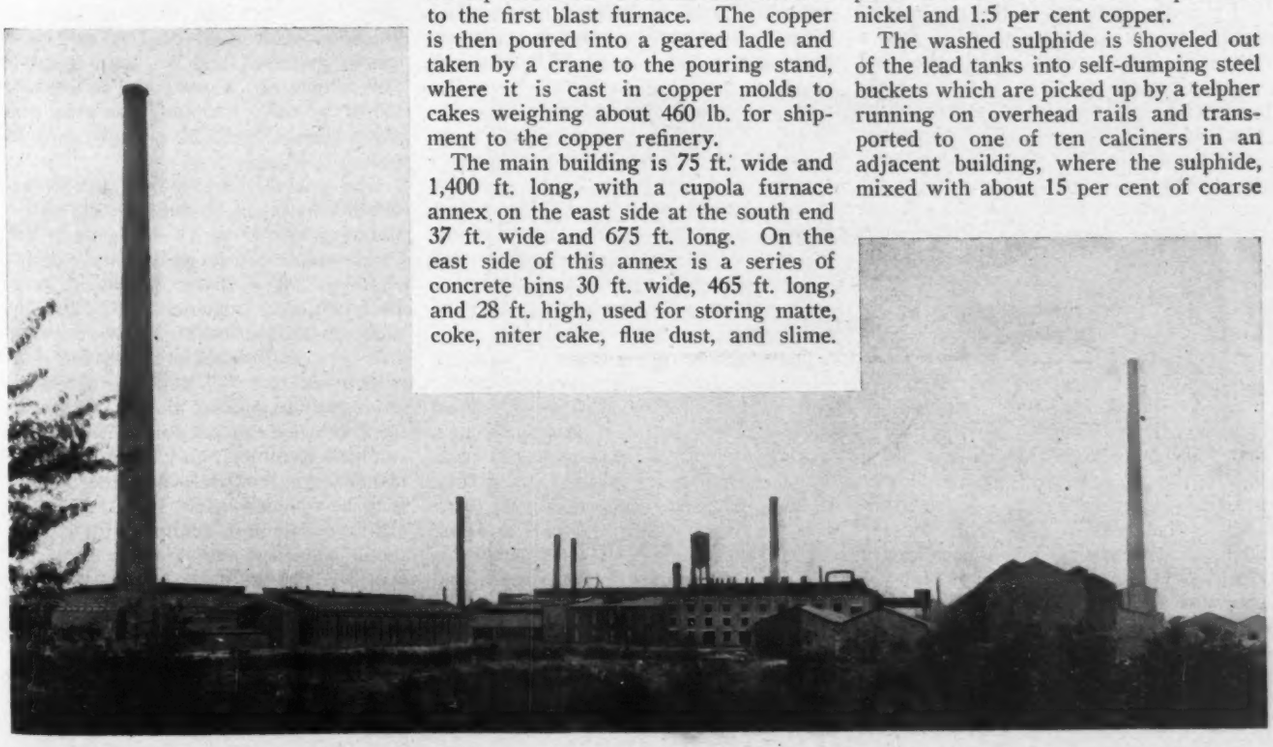
Blister copper from the acid shells is taken to one of two holding furnaces, magnesite-lined steel cylinders 10 ft. diameter by 15 ft. long, fired with oil. Here a part of the nickel, present as oxide emulsified in the copper, rises to the top and is skimmed off and reverted to the first blast furnace. The copper is then poured into a geared ladle and taken by a crane to the pouring stand, where it is cast in copper molds to cakes weighing about 460 lb. for shipment to the copper refinery.

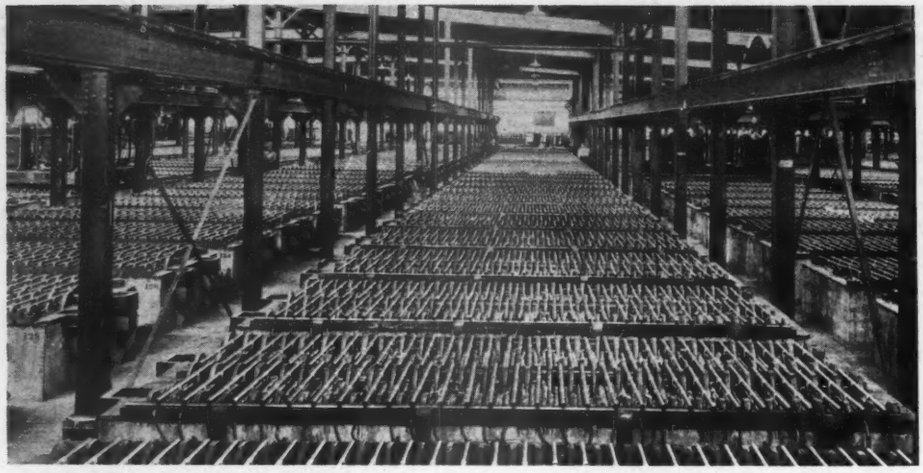
The main building is 75 ft. wide and 1,400 ft. long, with a cupola furnace annex on the east side at the south end 37 ft. wide and 675 ft. long. On the east side of this annex is a series of concrete bins 30 ft. wide, 465 ft. long, and 28 ft. high, used for storing matte, coke, niter cake, flue dust, and slime. An elevated standard-gage railroad track is laid full length to serve these bins. At the northwest end of the main span is the copper-pouring building, 29 ft. wide and 465 ft. long, where blister copper is poured into molds and shipped. This department is served with cross transfer tracks from the converters and with a 10-ton electric overhead traveling crane.

The wet-process building is adjacent to the furnace building. Here the second bottoms received on narrow-gage cars are first crushed in an 18x30-in. crusher to the size of duck eggs and smaller. Then the material is lifted on chain-and-bucket elevators to one of two ball mills on the upper floor, one being a No. 8 Krupp and the other a 7-ft. 6-in. Traylor mill. The outer screens are of rolled slot wire and have openings 0.027 in. wide. The ground sulphide is transferred in wheelbarrows and dumped into water contained in one of thirty filter-bottom, lead-lined, concrete leaching tanks, 14x12 ft. by 4 ft. 6 in. deep, holding about 135,000 lb. sulphide for each charge. When the tank is filled, hot water is percolated through the sulphide to wash out sodium sulphide. This requires about 36 tons of water per tank, and 48 hours. The strong sulphide leach liquor is pumped to storage, but the dilute wash flows to waste.

After washing out sodium sulphide, hot dilute sulphuric acid is added to dissolve selectively the iron, about 50 lb. of 66-deg. acid being used per ton of sulphide. Considerable nickel as well as iron is dissolved; therefore, the strong liquors are saved in storage tanks to be dealt with as described later on. Material is now known as washed sulphide and contains about 74 per cent nickel and 1.5 per cent copper.

The washed sulphide is shoveled out of the lead tanks into self-dumping steel buckets which are picked up by a telpher running on overhead rails and transported to one of ten calciners in an adjacent building, where the sulphide, mixed with about 15 per cent of coarse





Mastic-lined concrete tanks, in the electrolytic department, are built in blocks of two each

salt, is subjected to low-temperature calcination to chloridize the copper.

Each of the calciners is in part mechanical and in part hand-worked. The mechanical hearth is provided with an Edwards rabbling mechanism, there being 24 water-cooled rabble arms 39 in. long making ½ r.p.m. Each arm has five stirrer blades of cast nickel, and the circular areas stirred by each arm overlap so that the material under treatment is gradually moved from the feed (flue) end toward the fire end of the hearth. The temperature near the feed end is only about 1,100 deg. F., but it gradually rises until at the hot end of the mechanical hearth it is about 2,200 deg. Doors 10x14 in. on 48-in. centers along the sides give access to the stirrer arms for renewal of blades or other necessary attention.

From the hot end of the mechanical hearth to the fireboxes there is first a space of 22 in., over which the roof rises sufficiently to cover the upper, high-temperature, hand-worked hearth which receives the direct flame of the fires. At the end of the mechanical hearth begins the lower, low-temperature, hand-worked hearth, whereon the chloridizing of the copper is completed. This hearth is 23 in. lower than the level of the mechanical hearth and its roof constitutes the upper high-temperature hearth. Three doors are provided on each side for rabbling and moving the material.

The two hearths just described are worked on a batch system. When sufficient partly calcined and chloridized material has collected by falling from the mechanical hearth to the lower hearth, 12 per cent salt is rabbled in and the batch is paddled along under the arch constituting the upper hearth. Here it is allowed to remain for 24 hours at a temperature of about 1,100 deg., which completes the chloridization of the copper. The material is then raked out into steel telpher buckets and taken back to the wet house.

The chloridized material is discharged from the buckets into one of six leach tanks the same as those described in the foregoing, and there washed with hot water to leach out cuprous chloride. Some nickel also goes into solution. The green leach liquor is first led over copper scrap to cement out such platinum metals as may have gone into solution, and then it goes to storage tanks. The leached material is now known as green nickel oxide, containing about 74 per cent nickel and 0.1 per cent copper. Some of it is packed in barrels and shipped as such, but most of it goes to the next process.

Green oxide not barreled and shipped as just described is shoveled out of the leaching tank and carried by the telpher back to the calciner, where it is mixed with about 20 per cent of soda ash and put on the upper high-temperature hearth thereof. Here it is heated to about 2,200 deg. F. and is rabbled every twenty minutes for twenty hours, when it is drawn from the furnace and taken back to the wet house. The final calcination requiring so high a temperature, the two furnace fireboxes are liberally dimensioned. They have manually operated cast-iron rocker grates 5x6 ft., and carry deep fires so as to make a long flame with the 38 per cent volatile coal that is used. The flame and gas pass over the material on the upper hearth and then drop down to enter the mechanically operated part of the furnace.

The furnace gases are led through dust flues built under, and extending beyond, the fire ends of the furnaces. They then enter an underground flue, whence they pass into one end of a two-compartment dust chamber 310x64x 30 ft. high. Each chamber is hung with iron wires about 10 gage and on 4½-in. centers. These have proved very efficacious in arresting dust particles, and remarkably little valuable material is lost by way of the stack. The dust chamber is connected at its cold end, by a short brick flue, to a concrete stack similar to the one on the furnace and converter system.

Upon its return to the wet house the product of the second, high-temperature calcination is dumped into one of twelve leaching tanks, where it is washed with hot water to remove sodium salts. As only a small amount of these has combined with sulphur, the leach solution contains considerable basic material for precipitating out copper and nickel from the leach solutions previously made. All four of the leach liquors are mixed together, supplementing any deficiency in bases by additions of milk of lime, whereby the copper and nickel from the second and third leaches are precipitated as hydroxides or as sulphides by the sodium sulphide in the first leach solution. After settling and decanting, the precipitate is filtered in one of four 30x30-in. cast-iron recessed plate presses. The filtrate is discarded and the press cake goes to the first matte-smelting furnace.

The black nickel oxide, which is the final product of the wet house, contains about 77.8 per cent nickel, 0.1 per cent copper, and from 0.005 to 0.010 per cent sulphur. Only a relatively small amount of nickel is now sold as oxide, the major portion being sold as electrolytic nickel made as described in the next step of the process.

For providing material for anode metal to be used in the production of electrolytic nickel, sulphide as received from the furnace department is not ground so fine as when it is to be used for the production of oxide. The water leach for removing sodium sulphide works satisfactorily on fairly coarse material, and the acid leach to lower the iron content may be omitted. When grinding sulphide for this purpose, the ball-mill screens have ¼-in. square openings.

The coarsely ground, water-leached sulphide is taken by the telphers to the sintering plant, which is housed in a building 108x176 ft. next to the calciner building. The plant includes seven Dwight-Lloyd machines, 42x252 in., with material-handling and crushing and grinding machinery. Here the sulphur is removed and the nickel, as oxide, left in a form that is acceptable to the nickel anode furnaces. Nickel sulphide is difficult to calcine except at rather high temperature if the sulphur is to be reduced below 1 or 2 per cent; ordinary calciners dealing with it have small capacity and are expensive to operate. On the other hand, the sintering of sulphide with sufficient removal of sulphur proceeds rapidly, and, despite the necessity for recirculating a large proportion of the sinter, is a relatively cheap operation if suitable equipment is provided for the purpose.

The machines are placed in a row at about 16-ft. centers. The tops of the wind-boxes are flush with the third floor of the building and their dust hoppers extend down to within 36 in. of the ground floor. In themselves, the machines do not present any unusual features. The sides of the pallets carrying the grates are 7½ in. high, as it is found desirable to use a fairly deep bed. The grate bars are 8x21 in., so each extends halfway across the pallet. They are each perforated with conical holes ⅜ in. diameter at the upper surface and ⅛ in. at the lower. The oil flame for ignition is directed across the bed through a brick-lined inverted trough carried on brackets. Fairly high temperature ignition is essential, so about fifteen gallons of oil are burned per machine hour. The distribution of the charge on the grates is effected by the usual swinging spout arrangement. Blast pipes connect each machine to its fan, which is an 8x84-in. Sinter Corporation machine, having a capacity of 14,000 cu.ft. air at 750 r.p.m. Each fan is driven by a 125-hp. motor through a Tex-rope drive, and is provided with roller bearings.

Arrangements for proportioning the feed include, for each machine, a bin each for sulphide, coke breeze, fine sinter, and coarse sinter; these are of cylindrical, conical-bottomed steel construction. The conical bottoms terminate in a cylindrical steel ring 36 in. diameter by 12 in. high, which has a loosely fitting steel ring collar adjustable for height surrounding its lower part. Immediately below this is a rotating cast-iron disk, 56 in. diameter, upon which rests an adjustable scraper plowing off a steady stream of material as the disk revolves. The four bins and their feeders are in line, so the material plowed off each of the disks falls upon a conveyer belt which carries it to an elevator boot, whence it is elevated to the mixers on the fourth floor. Both feeders and feed belts are on the second floor, where their performance may be easily watched.

The machine product is discharged in the usual way as the pallets descend at the end of the machine. Each machine discharge end is partly inclosed in a hood which terminates at the top in a stack to carry off steam; at the bottom is a roll feeder which retains the product within the bin which constitutes the lower part of the structure, and which receives and retains for a time the sinter discharged from the machine. A water spray directed upon the material in the bin effects some cooling.

Material fed from the roll feeders falls upon a horizontal steel pan conveyor 36 in. wide by 120 ft. long, which carries it to the end of the line of D-L machines and drops it upon the lower end of a similar conveyor at right angles to the first and inclined at such an angle as to elevate the material to the third-floor level in a horizontal distance of 65 ft. Here the sinter is dropped into a perforated steel-plate trommel 4 ft. in diameter and 8 ft. long. The principal function of this trommel is to separate the badly sintered, high-sulphur fines from the well-made sinter. Undersize falls through a chute to an elevator which lifts it to the return bins, while the oversize falls into a 18x30-in. crusher.

The crushed sinter is next elevated by a chain-and-bucket elevator to a 5½-ft. Symons cone crusher set at a minimum opening of ⅜ in. The discharge falls on a 24-in. pan conveyor, which discharges into the boot of a 9x12-in. bucket elevator extending to the top of the building. Then the material is delivered onto a 4x8-ft. Hum-mer two-surface screen, the upper surface having ⅞-in. square openings and the lower ⅜-in. square openings. Oversize from the top surface falls on belt conveyors and is delivered to grate layer hoppers located on the feed end of each sinter machine, where it is distributed onto the machine grates. The intermediate size from the screen drops into a 20-ft. diameter conical-bottom product or finished-sinter bin on the top of which the Hum-mer screen equipment is installed. Fines drop through a chute onto a drag chain conveyor, which delivers to belt conveyors supplying the previously mentioned feed bins, and thence again to D-L machines. The arrangement of hoppers and dampers under the Hummer screens allows the diversion of coarse or fine products to points desired. Washed sulphide is brought and dumped into proportioning bins direct by telpher and dump buckets.

Present practice is to set the disk feeders to make a mix with about 3 to 5 per cent sulphur and about 2 per cent coke breeze. It is quite essential to use some coke breeze, and efforts to dispense with it by using a larger proportion of green sulphide have not been successful. The operating temperature is high and the sulphur is commonly reduced to about 0.4 per cent or less, which is quite satisfactory.

The finished sinter is taken to the anode furnace building in side-dump narrow-gage steel cars holding about 7,000 lb., hauled by a gasoline locomotive. There it is dumped into a pit, whence a chain-and-bucket elevator raises it to a storage bin. Low-volatile coal crushed to ¼ in. and under is similarly elevated to a coal-storage bin. Disk feeders under each bin deliver proportional amounts of coal and sinter (2:10) to a belt conveyor, whence the mixture falls into steel buckets which are lifted by a bridge crane and dumped into the feed hoppers of one of the seven anode furnaces.

The furnaces are of the oil-fired open-hearth type. The hearth, 25x10 ft., is built upon cast-iron plates 1½ in. thick, which rest on 10-in. 22.4-lb. steel beams set at right angles to the length of the furnace and supported on brick piers. Hearth, side walls, and roof are made of Arco brick, with magnesite brick in the side walls at the slag line. The roof is arched 1.3 in. per foot and is 9 in. thick. The skewbacks are horizontal for 13 ft. 8 in. from the front, and then slope down toward the offtake. They are 3 ft. 10 in. above the hearth in the horizontal part and 1 ft. 10½ in. at the back. Buckstays are 12-in. 31.8-lb. beams, and tierods are 1¼ in. in diameter. The three feed hoppers are of steel, supported by a platform on columns at 5-ft. centers, so that they may discharge into feed holes 9x9 in. along the center line of the roof.

Fourteen 27x36-in. anodes, weighing 425 lb. each, are carried in a rack

Two tap holes are provided, each with a swing spout 11 ft. long. Beyond the back wall in the newer furnaces is a small dust chamber the width of the furnace and 7 ft. long by 17½ ft. high. This has an opening 8x6½ ft., through which the hot gases are drawn through the waste-heat boilers.

The newer boilers are of the Babcock & Wilcox horizontal water-tube type, having 4-in. tubes and an available heating surface of 4,640 sq.ft. They operate at 150-lb. pressure, and each evaporates about 15,000 lb. of water per hour. The steam is used in part to drive the converter blowers in the power house and in part to heat solutions in the wet house and the cementation end of the electrolytic nickel department.

Each furnace is fired with five Maxon oil burners whose axes are about 24 in. above the hearth level. About 164 gallons of oil are burned per hour, the draft being produced by a steel-plate motor-driven fan, which draws the gases through the furnace and boiler and discharges them into the bottom of individual brick-lined steel stacks 48 in. in diameter and 100 ft. high.

THE furnace charge is about 65,000 lb. sinter, 16,000 lb. coal, and 25,000 lb. anode scrap. The cycle is about 29 hours, whereof charging and melting require 27½ hours, and tapping, using two spouts, requires 1½ hours. On the average, the amount of metal tapped is about 75,000 lb. Each charge produces also about 5,000 lb. of slag, which is shipped back to Copper Cliff.

The anode molds are of cast iron mounted on two cast-iron 16-in. wheels. They have wrought-iron handles similar to those used on the old-fashioned hand-pulled slag pots. To prevent shrinkage stresses breaking the anode lugs, the molds have loose blocks at the place where such stresses would be transmitted to the molds. These loose pieces are removed as soon as the anode metal in contact with them has frozen.

Two of the furnaces are set apart for melting nickel cathodes to make blocks of various weights, nickel shot, and "F" shot. Cathode nickel is melted and brought to correct pitch for pouring, and, in the casting of blocks, is poured into molds of cast iron mounted on wheels like the anode molds. Each mold for 50-lb. blocks has five depressions, and each of those for 25-lb. blocks has six. When making nickel shot the metal flows from the end of the furnace spout into a water bosh 15 ft. 10 in. by 8 ft. 8 in. and 8 ft. deep, which is fed with water from a 4-in. pipe. Depending on the manner in which the metal is poured, fine or coarse shot may be made.

"F" shot is made by adding to the molten metal a sufficient quantity of high-grade ferrosilicon in a ladle and then pouring the alloy into water. Some of the silicon is oxidized, and flickering hydrogen flames occur at the surface of the water. The "F" shot is required to be small, so a pouring spoon with four small notches is used to receive the stream of metal from the ladle and distribute it in four smaller streams. After drying and screening, "F" shot is packed in six-hoop wooden barrels for shipment. It ordinarily contains about 5.6 per cent silicon.

The anodes are rather rough on top, but are sufficiently uniform as to thickness. After being removed from the molds they are stacked upright, resting on their lower ends, and by a portable electric grinder the lower side of the lugs is brightened to make good electrical contact on the tank busbars. They are next picked up in groups of fourteen by a clamp carried by the crane, and placed in racks standing on narrow-gage steel cars for transfer to the electrolytic nickel department. Each car carries two racks of anodes. The cars are 6½ ft. long by 3¼ ft. and have 14-in. flanged wheels. They are drawn by a gasoline locomotive.

The electrolytic department is housed in a building 350x700 ft. At the north end is the substation for this department, 37x420 ft. The building proper has two floors; the ground floor is mostly covered by the plating tanks, which stand upon concrete beams 14x24 in., carried by concrete posts 14x20 in., but at the north end is the narrow-gage track whereon anodes are brought in and cathodes and anode scrap taken out. At this end also are the scrap washers mentioned further on. At the south end are the pumps for lifting foul electrolyte to the purifying system.

ON THE upper floor, at the north end, is the "working floor" or space where starting blanks are stripped and conditioned, starting sheets made and packed in racks, and cathodes washed and soaked. Here, also, opposite each of the seven units, is a hatchway 4 ft. 9 in. by 14 ft., its center being over the center of the narrow-gage track on the ground floor, through which racks of anodes are lifted by a crane, and racks of anode scrap or of washed cathodes are lowered to cars standing on the track.

The working floor is served by seven 3-ton bridge cranes, one for each unit. Cranes are electrically operated, but are controlled from the floor. They serve to raise and lower racks from and to cars on the ground-floor track, and to place racks of cathodes in the wash tanks. The racks referred to are made of 2-in. iron pipe, with welded joints, and weigh about 200 lb. There is a rail on each side at the top, of ⅝x3-in. steel, upon which anodes are hung. Cathodes are supported on their lower edges on a board platform supported by the bottom cross pipes. Anodes are 27x36 in. below the lugs. They are of somewhat irregular thickness and average 425 lb. each. Each rack carries fourteen.

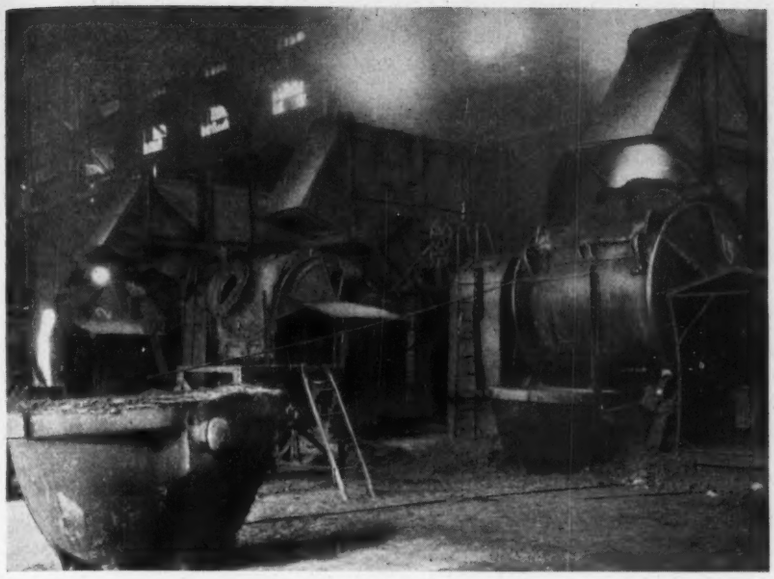
Starting blanks are aluminum sheets 29x38¼x$\frac{3}{16}$ in., with two tangs each 6x5¾ in., to the top of which is riveted and soldered the iron crossbar of ½x1¼-in. section. Side and bottom sticks 1-in. square are applied to these to prevent the starting sheet covering the edges. They weigh complete about 30 lb. Twenty are placed in each rack.

Starting sheets have two loops 2½x 20½ in. before bending, made by shearing some of the sheets, attached by Morrow clip machines. Two such machines are used. The sheets are 28x36 in. and weigh about 11 lb. each. A rack usually carries 75. The cathodes average about 128 lb. each, and a rack ordinarily holds about thirty of them, or 3,800 lb.

HANDLING electrodes into and out of the plating tanks is done from a bridge carried by a 25-ton crane, whereof there are two to each unit, one for each row of tanks. The bridges are of steel construction, each having two platforms 4 ft. 8 in. by 17 ft. 10 in., one on each side of a central opening 4 ft. 4 in. wide, which, when placed over a tank, gives access to the whole top thereof. The bridges are hung from the cranes by four cast-steel grips engaging on the lower flanges of four shoes riveted to the crane steelwork. They may be detached therefrom by lifting the bridges about an inch by hydraulic jacks on the working floor, when the crane may be moved back over the tanks, leaving the space over the now stationary bridge free to allow access to the bridge by the working-floor cranes.

When changing anodes, the bridges are loaded with five racks of anodes and three empty racks for anode scrap. When pulling cathodes the bridges carry four racks of starting sheets and four empty racks. When pulling starting sheets six racks of twenty blanks each are carried, with two empty racks. Two men working together operate each bridge. The bridge cranes carry a subsidiary beam crane of 13 ft. 7⅛ in. span, and 1,500-lb. capacity, with 17-ft. travel. This enables the bridge men to handle electrodes speedily without injury to the cathode boxes.

In units 2 and 3 there are 104 tanks each; in 4, 5, 6, 7 there are 156 tanks each. The tanks in 2, 3, 4, 5, 6, and 7 are of concrete, mastic lined, and built in blocks of two tanks each. The concrete walls are 6 in. thick, the mastic lining is 1½ in., and the dimensions inside the lining are 2 ft. 10½ in. by 16 ft. 9½ in., and 5 ft. 2 in. deep. At one end is a 2½-in. overflow pipe, opening at 6 in. above the bottom, and terminating in an overflow basin 8x9½x4 in. deep at the top of the tank. The overflow basin projects 7 in. beyond the outer end of the tank and has a level-regulating wooden dam and a perforated outlet, from which the rejected electrolyte rains down into a funnel, whence it is led to the foul-return launder by a short piece of hose.



Unusual conditions here make it necessary to use acid-lined converters for blowing copper to blister

Along the outer side of each tank is a hard-rubber header, connected at its center to a 1¼-in. rubber hose riser from the pure-solution main. Along the upper surface of the header are thirty hard-rubber nipples, to each of which it attached a ¼-in. soft-rubber feed pipe to lead pure solution to the cathode boxes. Along the tops of the sides are hardwood top-boards 2x6 in. They have notches cut out of their lower part to receive the ends of the wedges that secure the cathode boxes in place, and the outer boards have also ¾-in. holes opposite each cathode box through which the rubber feed pipes are led.

Within each tank are thirty cathode boxes. These are made of spruce wood and have sides of heavy canvas, which is calked into a groove along the sides and bottom rail of the box and tacked to the top rails. The legs of the boxes stand upon notched rails fastened against the sides of and 14 in. above the bottoms of the tanks. The notches insure correct spacing of the boxes.

Current is led to and distributed in each cell by (*a*) four copper bars, each $\frac{13}{32}$x4 in., which lead from the switchboard in the substation to the first cell in each circuit; similar bars connect each block of two cells, the bars being bent so as to extend from the five-sided distributing bar on the top board on each outer side of a tank down the side to a point under the floor, whence they proceed horizontally to the next block. At the end of the row of cells the copper is brought across to the second row, the last cell whereof is connected to the switchboard. (*b*) On the top board on each outer side of a cell is a five-sided bar of 0.6015-sq.in. section the length of the tank, on which one lug of an anode or one end of a cathode crossbar rests. The $\frac{13}{32}$x4-in. copper bars are electrically welded to the five-sided bars. (*c*) On the top board surmounting the center partition of each block is a copper bar having a section like two triangles connected by a flat with a width at the base of 2¾ in. and a cross-section of 0.828 sq.in. One lug of an anode or one end of a cathode crossbar rests on the apex of one of the triangular sections. This unusual section is used to minimize the length of anode lugs, nickel anode metal being much weaker than copper. The cathode crossbars are of 1-in. I P size, round copper bars, notched near one end to make good contact with the busbars.

Operating voltage is about 2.4 per cell with 4,800 amp.; temperature is about 135 deg. F. As there are about 405 sq.ft. of active cathode area, the current density is about 11.8 amp. per square foot. The usual rate of flow of electrolyte into each cathode box is about 0.7 cu.ft. per hour; hence the average outward flow velocity through the canvas sides is about 0.05 ft. per hour. This flow is swifter than the velocity of copper or iron ions moving under the unit potential fall between the anodes and cathodes, so they are thus excluded from the cathode side of the canvas. As the cathodes are immersed in a solution nearly free of copper and iron, and continually renewed by the flow of pure solution, the metal plated out contains only trifling amounts of these impurities. Nickel ions resulting from the dissolutions of anode metal have to travel from the plating cells through the cementation and iron-removal process and return via the pure-solution flow pipes, tank headers, and solution feed pipes to the cathode boxes before they may be discharged on the cathodes.

The flow pipes and the return-flow launder are of wood throughout; there is little current leakage and a net cathode current efficiency of 94 per cent is held month after month.

Anode slime in part falls to the bottom of the cells, whence it is removed periodically, and in part adheres to the anode scrap. The scrap is accordingly scrubbed with a stiff broom to loosen the often tightly adherent slime, which is then washed off with a stream of electrolyte. Scrap washing is done in stations on the ground floor, one for each unit.

The impure solution flows through wooden launders under the tank aisles to wooden pump tanks 19 ft. in diameter by 7 ft. deep. There are two such tanks for each unit. Thence it is pumped by centrifugal pumps to rectangular preheater tanks 6 ft. by 6½ ft. deep, where it is heated to about 180 deg. F. by steam coils. It then flows successively through a train of cementation tanks, there being six in each of units 1, 2, 3 and eight in units 4, 5, 6, 7. These tanks are 14 ft. in diameter, of wooden stave construction, 30 ft. deep. They have conical bottoms with a slope of 70 deg. Within each tank is a central tube 10-in. inside diameter reaching to within 15 in. of the bottom. The tubes are made of rubber similar to tire-tread stock and are reinforced with a helical wire winding embedded in the rubber. They are hung from the lower flange of an agitator which is in effect a vertical-shaft centrifugal pump having a practically clear discharge all around its circumference. It circulates about 320 cu.ft. per minute of the contents of the tank. The motors driving agitators are vertical shaft 25-hp. 720-r.p.m. induction motors. Metal powder resulting from reduction of green oxide with charcoal is used to cement out copper, about 7,000 lb. being kept in circulation in each tank.

THE de-coppered solution flowing out of the last tank goes to a Dorr thickener about 34 ft. in diameter by 10 ft. deep. The underflow, consisting largely of metallics suspended in about ten times their weight of solution, is pumped back to the first cementation tank, while the overflow goes through a train of four blow-tanks each 8½ ft. in diameter by 30 ft. deep. Air is blown into the solution to oxidize iron, which is then precipitated as ferric hydroxide. A suspension of nickel carbonate in water is fed in to neutralize the acid set free by hydrolysis of ferric iron.

After passing through the blow-tanks, the solution is filtered in 42-in. wooden plate-and-frame filter presses, whereof there are five in each unit. Centrifugal pumps are used to develop about 30-lb. pressure. The clear filtrate flows to the 16½-ft. diameter by 10½ ft. deep head tanks, two to each unit, and thence via regulating boxes and wooden flow pipes to the plating tanks to complete the cycle.

The purified electrolyte contains nickel sulphate equivalent to about 40 grams nickel per liter, and about 20 grams boric acid. Copper and iron should each

be less than 0.005 grams per liter. Hydrogen ion concentration equivalent to *pH* 4.8 to 5.2 is satisfactory.

To return to the nickel cathodes: after being washed and soaked overnight in warm water to insure removal of nickel salts, they are taken to the cutting and shipping building adjacent to the electrolytic building. Here they are, if required, cut to such sizes as are ordered, or stacked for stock. Two gate shears are used for cutting, one, with 56-in. knives, making 31 strokes per minute, and the other making 26 strokes. The shears are driven by motors mounted on the frames. The cut metal is packed in six-hoop wooden barrels holding from 1,000 to 1,500 lb. each, depending on the size of pieces. Whole cathodes are shipped loose in box cars or are packed in wooden boxes holding up to 800 lb. each for export. Loops and other cutting scrap are sent to the furnace department to be melted and poured as shot or blocks.

ANODE slime is pumped by centrifugal pumps into a 30x30-in. wood plate and frame filter press. The press cake is calcined in a coal-fired Edwards furnace having 28 mechanical rabbles. The sulphur is reduced to about 0.2 per cent and the calcine is then smelted with coal in an oil-fired open-hearth furnace similar to the furnaces used for making primary anodes but with a hearth only 15½x5 ft. It produces about 20,000 lb. metal per charge. The metal is cast in regular anode molds forming secondary, or Precious-Metal, anodes. These are corroded in regular tanks set apart for the purpose. To prevent loss of the very high-grade slime, the "P.-M." anodes are clothed in closely woven cotton-duck wrapping. The anode scrap is carried to the "P.-M." slime concentrating building, where the slime is carefully removed from the scrap, which is then returned to the "P.-M." anode furnace. The "P.-M." anodes contain about 24 per cent copper and 73 per cent nickel. Secondary slime contains about 2 per cent of platinum-group metals and is concentrated by acid treatment to a product containing from 40 to 50 per cent platinum-group metals, which is soldered up in steel cans and shipped to the platinum refinery in Acton, London, England.

The substation serving the electro nickel house also serves for stepping down and distributing electric power to other buildings. Power at 25 cycles and 46,000 volts is taken from the transmission lines of the Ontario Hydro Electric Commission. Main disconnecting switches and lightning arresters are on an outdoor switching structure.

From the switching structure the lines are led into the substation to two total-load circuit breakers and thence to the high-tension bus. There are ten three-phase 1,200-kva. water-cooled transformers, each serving a 1,100-kva. 225-275-volt rotary converter to supply direct current to the nickel cells. Each machine normally feeds the circuit it is assigned to, but one machine is connected to a transfer bus which may be switched into any circuit.

Power for various motors throughout the plant is taken from five 2,000-kva. transformers and one 1,500-kva. three-phase transformer, which step the voltage down to 2,000 and 575 volts, at which the power is used on the 554 motors throughout the plant. All the 550-volt motors are operated from push-button controls located in rooms built to house them. Total connected load is 25,200 hp.; the usual operating load about 14,000 hp. The load factor is better than 90 per cent and the power factor varies from 93 to 95 per cent.

The power house is equipped with four water-tube boilers, each with about 4,600 sq.ft. of heating surface, and with chain-grate stokers. They supply steam at 180 lb. and 150 deg. superheat to the following turbo blowers for copper converting, each of which delivers from 10,000 to 15,000 cu.ft. of air per minute at 15-lb gage:

One 3-stage steam, single-stage air, 7,750 r.p.m.

One 4-stage steam, 3-stage air, 3,550 r.p.m.

Two 3-stage steam, 2-stage air, 8,500 r.p.m.

Condensers maintain a vacuum of about 27 in. An air compressor of 1,000 cu.ft. per minute capacity supplies air to tools, barrel lift, and complementary apparatus, and the usual water-supply pumps are provided. There are well-equipped machine, forge, electrical repair, carpenter, and cooperage shops, and a laboratory.

International Nickel's Properties

THE principal properties of Inco of Canada include: nickel-copper mines in the Sudbury district of Ontario, and a colliery at Pontardawe, Wales; smelters at Copper Cliff and Coniston, Ont.; hydro-electric power plants at Turbine, Wabageshik, and Nairn Falls, Ont.; refineries at Port Colborne, Ont.; Acton, London, England; and Clydach, Wales; rolling mills at Birmingham, England, and Huntington, W. Va.; foundry at Bayonne, N. J.; research and technical laboratories in Birmingham, England, and Bayonne, N. J.; and development bureaus in Paris, France, and Frankfurt-am-Main, Germany.

The stock-market valuation of the company's properties, as represented by the value of its common and preferred stock at the end of October, 1930, was approximately $300,000,000.

THE BAYONNE FOUNDRY

—E. S. Wheeler
Superintendent

THE Bayonne plant, known as "The Foundry," is located at Oak St. and Hobart Ave., Bayonne, New Jersey, and covers approximately five acres.

For melting and refining, the following equipment has been provided: three oil-fired reverberatory furnaces, having a capacity of one to three tons; one Moore rapid "Lectromelt" electric furnace of 500-lb. capacity; one Detroit electric rocking furnace of 250-lb. capacity; four crucible melting pits; and one Whiting cupola.

Molding is done either by hand or machine, the latter equipment embracing Mumford, Osborne, plain, jolt, and squeeze molding machines; also a core-making machine. Molds and cores are baked in ovens, of which there are three. A centrifugal casting machine has recently been installed.

Connected to the casting building is the pattern shop, fully equipped with modern machinery for this work; a change house; and the concentrating department. In this department is a Marcy ball mill for crushing sand and metal, a concentrator, and special magnetic separator for reclaiming metal from the used sand. The sand shed, metal storage room, and casting finishing department are also connected with the foundry building. The finishing building contains sand-blasting apparatus, saws for cutting gates and risers, polishing wheels, and a complete machine shop.

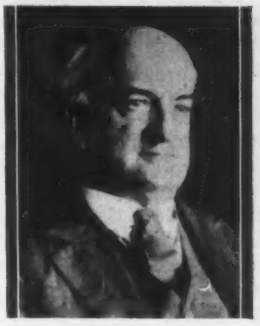
To insure pure Monel and nickel castings and blocks of proper composition for outside foundry use, there is a modern chemical laboratory for control purposes. The warehouse is used for the storage of metallic nickel (shot, electrolytic, and pig) of Canadian production, to take care of local trade, and cold-formed Monel metal and nickel angles and welded Monel metal tubing.

The function of "The Foundry" is not only the production of Monel metal and nickel castings, but also the production of sand-cast Monel, nickel, Everbrite, and nickel-copper-chromium alloy blocks for the production of castings by foundries throughout the country. The latter blocks are used for the production of "Ni-Resist" castings, a corrosion-resistant cast iron.

THE BRITISH EMPIRE'S LARGEST COPPER REFINERY

—*C. H. Aldrich and J. K. Bryan*

Manager, U. S. Metals Refining, and Superintendent, Ontario Refining, respectively



THE Sudbury district, prominent in the nickel world for many years, has in the past contributed a large tonnage of copper, recovered mainly as a byproduct from nickel refining. Formerly this copper was sent to an electrolytic refinery in the United States, but with the completion of the new plant of the Ontario Refining Company, Limited, at Copper Cliff, most of the copper from the nickel district will be refined where it is mined and smelted.

Situated across the flat from International Nickel's smelter, about 6 miles west of Sudbury, the plant is served by both the Canadian Pacific and Canadian National railways. Proximity of blister supply and good shipping facilities to markets make the location of the plant a strategic one. At the start of operations, the principal blister supply is being received from the Port Colborne refinery of International Nickel, but upon completion of that company's copper-nickel separation plant at Copper Cliff, at present under construction, the blister will be shipped directly from the smelter to the refinery over a private railroad. Copper produced by the Granby company in British Columbia is also being refined here, and copper from other Canadian sources may be received later on, though the Frood mine seems likely to continue to supply the bulk of the tonnage.

The new plant, with an initial capacity of 120,000 tons per annum, is the first electrolytic copper refinery in eastern Canada, and the largest in the British Empire. It consists of casting buildings; pig, refined copper, anode, and cathode storage buildings; electrolytic department, power house, store house, machine shop, administration building and laboratory, coal pulverizer, silver refinery, nickel recovery plant, and pumping equipment.

The severe climate presented unusual problems. It seemed desirable that all operations should be housed. Transportation should be reduced to a minimum, and a straight-line flow of material through the plant secured. Easy expansion to twice the initial capacity should be provided for.

In the layout adopted, the furnace building was placed at right angles to the tank house, rather than parallel with it, permitting a direct movement of anodes into the working aisle of the tank house, and of cathodes to the cathode storage. Corresponding materials are stored on each side of the anode- and wirebar-casting buildings, so that no outside transportation is required in either instance. Doubling the capacity of the plant would only involve the addition of one more furnace in the south end of each furnace building and the construction of four more bays at the north end of the tank house.

The main buildings, containing 8,000 tons of structural steel, are mounted on concrete foundations, upon which rests a section of red brick approximately 8 ft. high supporting the 200,000 sq.ft. of 8-in. interlocking tile which form the walls of the structure. On the roofs of the buildings are 600,000 sq.ft. of 3- to 5-in. poured gypsum covered by standard roofing of four-ply asphalt-impregnated felt. In the yard and storage about 5 miles of 85-lb. rail on standard-gage track, and 9 miles of 56-lb. rail on 2½-ft.-gage track, have been laid. Rolling stock consists of one standard-gage 30-ton gasoline locomotive, four 2½-ft.-gage 8-ton gasoline locomotives, 225 double-track narrow-gage industrial cars, 40 tank-house rack cars, and 30 slag cars. All equipment is fitted with roller bearings and automatic couplers. For general hoisting purposes, a 25-ton standard-gage gasoline-driven locomotive crane is used.

The buildings, having a total cubical content of 23,000,000 cu.ft., are placed in the approximate center of a 60-acre plot just west of the Copper Cliff railroad station, surrounded by a non-scalable anchor-post fence. A scale house, outside of the inclosure to the south, accommodates three standard-gage cars at a time, so that the car on either end may serve as a windbreak when the middle car is being weighed.

Incoming blister is received in box cars which are shunted directly into the pig storage building. This is a structure 880 ft. long, 60 ft. wide, and 40 ft. high, of structural steel and transite, with two 10-ton overhead cranes. Two light gantry cranes unload the pig onto narrow-gage cars, which proceed to twin track scales for a double weighing. They are then switched to the drill room, where a $\frac{13}{32}$-in. hole is drilled in each pig according to a templet, using a swivel radial drill. Samples are ground in a Hance mill, cut down by a riffle, and screened. Moisture determinations are made in a sand-sealed electric oven. A thermostat prevents the temperature from going over 350 deg. F., which might oxidize the copper.

The anode-casting building is of brick and tile construction on reinforced concrete foundations. It is 403 ft. long and 149 ft. wide, divided into three sections: a charging aisle 44 ft. wide, a furnace aisle 35 ft. wide, and a casting aisle 70 ft. wide. In the charging aisle are two 4-ton overhead cranes that normally charge sixteen pigs of copper into the furnace at once. Two 10-ton service cranes operate independently on a second runway above.

All three reverberatory anode furnaces have a capacity of 300 tons each. Their bottoms rest on cast-iron plates set on 4-ft. concrete piers; a layer of

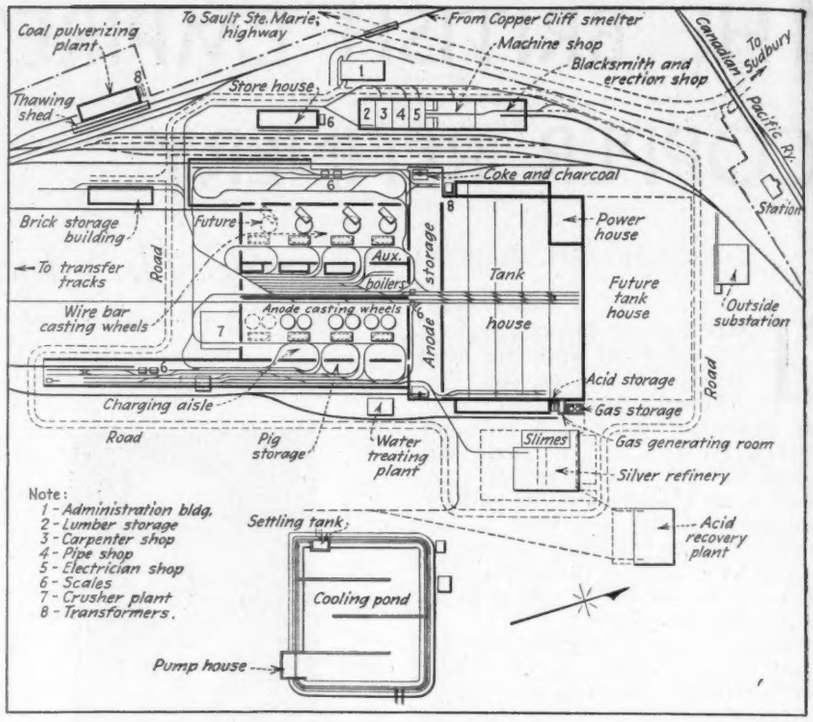
concrete forms the inverted arch, surmounted by two 12-in. layers of silica brick. The walls are of magnesite brick below and clay brick above the metal line. A course of 20-in. silica brick forms the roof. Waste gases from each furnace pass into a 640-hp. boiler having a working pressure of 175 lb., with 100 deg. superheat. The pits under the furnaces slope toward the charging side, where specially designed run-out pits are constructed, equipped with automatic sump pumps and electric alarm should water collect.

The anode casting aisle is equipped with six 36-ft. heavy Walker wheels, two per furnace, each holding 22 anode molds. This makes it possible to cast 100 tons of anodes per hour, and the anode cycle can be completed in 22 hours. Each wheel is driven by a 15-hp., 550-volt, three-phase electric motor direct connected to an oil drive.

Cast anodes are raised in the mold by a hydraulically operated knock-out pin and placed in cooling boshes by a pneumatic take-off, designed for this plant. Each cooling bosh has a capacity of 60 anodes and is equipped with a chain conveyor, upon which the anodes are hung and which moves a definite distance toward the head of the tank as each anode is deposited upon it. When a tank load of anodes has accumulated in the bosh it is removed by a rack suspended from one of the two 10-ton casting-aisle cranes, placed in a rack car on the transfer platform running along the west side of the casting aisle, pulled across a scale at the north end of this aisle, and thence to storage or directly into the tank house.

A covered aisle, 80 ft. wide, known as the anode-storage building, connects the casting buildings with the tank house. It runs the length of the tank house and is served with two 10-ton cranes. This building is used as an intermediate storage for anodes and cathodes, for trimming and straightening anodes when necessary, for shearing cathodes, and storage of coke for the anode and wirebar furnaces.

The electrolytic tank house, including the machinery bay and power house, is a fireproof structure 480x380 ft. To maintain a proper working temperature during the winter, it was carefully insulated, the outside walls being of 8-in. interlocking tile; all outside windows double; and the roof composed of a 5-in. slab of gypsum, cast in place, covered with standard four-ply roofing. Three large fans at each end of the building draw air from the outside or from the interior of the building through unit heaters; the heated air is distributed by a system of ducts. About one-third is blown into the cellar underneath the tanks, to prevent condensation and to provide good ventilation. Air containing excess moisture will be blown out through ventilators in the tops of the monitors. Thus, the dew point is never reached in the room and condensation



General arrangement of plant

and resultant drip are avoided. Interior steelwork is painted with a special acid-resisting asphalt paint, covered with a coat of gray, and finished with a coat of aluminum paint.

Particular attention has been given to the floor, which is of concrete, overlaid with a course of acid-proof, vitrified brick, bedded in asphalt. The brick was laid with open joints flushed with asphalt which was carefully ironed in to give a smooth, impervious surface. Asphalt mastic fillets were poured around and ironed in to the base of all concrete and steel columns to a height of 3 in. above floors, platforms, and walkways, to prevent corrosion from drip.

The electrolytic cells are placed on insulating tiles resting on concrete piers, 9½ ft. above the cellar floor. This provides ample headroom, so that busbars, mud launders, and circulation pipes may be installed under the working floor without obstructing walkways through the cellar. The room contains 1,216 cells (regular and stripper) arranged according to the Walker multiple system in 32 sections of 38 cells each. Each cell is 11 ft. 3 in. long, 3 ft. 6 in. wide, and 3 ft. 9½ in. deep, inside dimensions, and is of sectional construction composed of precast, reinforced concrete slabs, arranged so that no short circuits between the cells can occur through the reinforcing steel. The concrete slabs were cast on a 3-in. wood deck with steel sides, using a 1:1½:2½ concrete mixture, and the two layers of ¼-in. welded wire mesh employed for reinforcing were cut carefully away from edges and bolt holes to avoid short circuiting. The sides were 4¾ in. thick, the ends 3½ in., and the bottoms, 4 in. All linings were of 6-lb. 6 per cent antimonial lead; the lead pipe was of 5 per cent antimonial lead.

Anodes, 37x36 in., weighing about 500 lb., are spaced 3½ in. apart, with 37 anodes and 38 cathodes in each cell. All cells are placed on the same level and have individual circulation, at the rate of about 4 g.p.m. The solution enters the cell at the bottom and is discharged into the return lines at the opposite end through an overflow at the top. The object of individual circulation is to permit a more even distribution of the addition agents and a better temperature control, an idea confirmed by the smoothness of the cathodes. All heating, storage, and supply tanks and pumps required for the circulating system are installed in the machinery bay, at present the north bay of the tank room.

Each of the two main circulating systems is equipped with two heating tanks and three vertical centrifugal lead pumps, of which one is a spare. The heating tanks are 72 ft. long, 11 ft. 6 in. wide, and 2 ft. 3 in. deep, made of structural steel with concrete-slab bottoms and angle-iron sides. They are lined with 8-lb. 6 per cent antimonial lead and have removable covers of lead-lined steel. The heating coils consist of forty 1½-in. Class AA lead pipes supported from 5 to 9 in. above the bottom and running lengthwise through the tanks. Low-pressure steam is passed through the pipes at such a rate that it is all condensed before leaving the coils. The condensed water is drawn out by steam-

operated, reciprocating vacuum pumps and forced up into a storage tank, from which it is drawn to supply wash water for cathodes and anode scrap and to make up for the evaporation of the electrolyte.

By changing plugs in the suction lines any two of the centrifugal electrolyte pumps may be used. Operating at a speed of 750 r.p.m., each pump has a capacity of 1,000 g.p.m.[1] against a 23-ft. head. Self-aligning ball bearings are used to support the shafts, and little attendance should be required. The stripper cells have a separate circulation to allow the special treatment needed for the electrolyte in this section. All tanks and pumps required for this circulation, as well as storage tanks for return solution from the silver refinery, are also situated in the machinery bay, and a 10-ton overhead electric service crane is installed.

The tank house is divided into two electrical circuits, each covering two bays running east and west, with a full load voltage of 160 at 12,000 amp. Two independent circulating systems running north cut the electrical circuits in the center of the room, giving a maximum tension of 80 volts between any two points in the system. This arrangement minimizes power losses and growth of copper by stray currents. As a further precaution, sections of hard rubber pipe are inserted in the main feed lines and long lengths of either soft- or hard-rubber hose or pipes are used in all inlets and outlets to the cells. A long section of mastic-lined wooden launder, separating the lead-lined launders, prevents loss of current through the slime-collecting system.

To permit movement of anodes and cathodes on a straight line in and out of the tank house, a center aisle of ample proportions for all charging, unloading, and washing operations was constructed. This aisle is 64 ft. wide and contains four narrow-gage tracks, straightening racks, wash boxes, and cathode unloading machines. Cars are moved by electric winches. Anodes are brought in on rack cars and lowered into the tanks by eight 10-ton stiff-leg rack cranes. The cathodes are pulled from the tanks by the same cranes, brought to the center aisle, washed, and removed from the cranes by three Burns cathode-unloading machines, which, in turn, stack them on narrow-gage cars for the wirebar furnaces.

Work aisles, 64 ft. wide, are at each end of the tank house. Racks for vertical stripping, slitting machines and shears for making loops, punches for attaching loops, and other equipment required for making the finished starting sheets are placed in the east aisle, adjacent to the stripper cells. Liberating cells, arranged so that they can be easily cut in or out of the circuit, are installed in both east and west end aisles. In the west aisle, at the end of the building opposite to the place where starting sheets are prepared, racks are placed for storage of anode scrap or of partly dissolved anodes used in cells as needed to replace light anodes that have become completely dissolved before pulling is scheduled. This arrangement facilitates the handling of scrap which otherwise would have to be stored outside the tank house.

In the blister handled here, nickel is a most important impurity. Pyne-Green segregating cells are used to concentrate nickel sulphate in the solution that is withdrawn. This solution, running about 2 per cent nickel and 1 per cent copper, is pumped to the acid-recovery plant east of the silver refinery. Here the copper is precipitated electrolytically and the resulting acid nickel sulphate solution concentrated, first in vacuum evaporators and then by direct heat, until the nickel separates as anhydrous nickel sulphate. The acid is removed from the salt by decantation and returned to the tank house; the nickel sulphate is washed and dried in lead-lined centrifuges and shipped to the nickel company.

The electrolytic slime, containing the silver and gold and other insoluble impurities, is discharged through a plug seat in the bottom of each cell and run through launders to a central sump, where it is screened and pumped to the silver refinery, consisting of three principal divisions: a slime room, a furnace room, and a parting plant. The buildings are the form of a U with the slime room across the ends, an arrangement permitting easy extension.

Slime is roasted and leached as usual for the removal of copper. The only novel feature of the equipment are large lead-lined centrifuges instead of filter presses or vacuum filters for separating and drying the slime. Dry slime is quickly discharged by vertical plows. Tests indicate a considerable economy.

The furnace building contains furnaces for roasting raw slime and flue products and a doré furnace, where the treated slime is smelted. Equipment is also provided for crushing and sampling slags that will be shipped out of the plant.

Doré is parted in mastic-lined concrete cells of the Balbach type for the acid treatment of gold mud. An electrically heated Duriron kettle is used. The gold sand from this kettle is cast into anodes and refined electrolytically in Wohlwill cells. Provision is also made for recovery of platinum metals from the gold electrolyte and residues. All gold operations are performed in rooms separated from the adjoining parting plant and silver refinery office by glass partitions.

Cathodes, loaded on narrow-gage cars, are pulled across the scales in the anode-storage aisle into the cathode-storage building, where sufficient trackage is available for car storage of 550 tons. The tracks in this building, as may be seen from the diagram of the plant, are connected directly to the loops running

[1]The Imperial gallon is used in Canada. Its ratio to the U. S. gallon is 5 : 6.

in front of the wirebar furnaces, so the cathodes can be charged and the empty cars returned either to the cathode storage or to the tank house with a minimum of haulage.

The charging aisle, furnaces, and waste-heat boilers in the wirebar furnace building are practically duplicates of the anode-furnace equipment. For casting, 40-ft. diameter Clark wheels are used, built with especial care to secure stiffness and smooth running so that a good set of the finished shapes can be obtained. They are rope-driven, and smooth acceleration and deceleration are secured by an oil drive between the motor and cable winch. This satisfactory arrangement permits starting the wheel as soon as the bars have been poured without waiting for the surface to solidify, which of course results in quicker casting. Two ladles are used and eight bars are cast at a time.

The cast copper passes over sprays and is cooled from beneath while the copper sets, without spraying from above until the molds are nearly to the dumping point and below the steam hood covering the bosh. They are then dumped on a conveyor placed at an angle of 45 deg. from the building line, which takes them out of the water and delivers them to an inspection conveyor, 35 ft. long, in the wirebar storage building. Thence the wirebars are taken by an air lift, stacked, and transferred to cars at the scales by one of the 10-ton electric cranes. After weighing, they are either moved to the shipping platform, where they are loaded into box cars by a gantry crane, similar to the cranes used for unloading pig, or transferred to stockpiles in the building by one of the overhead cranes. This arrangement eliminates all narrow-gage transportation between the wirebar casting building and the refined-copper storage and makes the handling of the copper extremely easy.

Each furnace has a separate tap hole for drawing copper when making molds. For wirebar molds the copper runs through a launder directly to the nearby mold press. A bull ladle carried on the crane is used when anode molds are cast. The equipment for making anode molds is at the extreme south end of the wirebar casting aisle. Here the molds are cast in thoroughly dried sand in an oil-fired furnace.

All furnaces and the auxiliary boiler are fired with pulverized coal made in a central pulverizing plant. A thaw shed is provided for use in cold weather, and the coal is then crushed and elevated to overhead storage bins. It is dried in a coal-dust-fired dryer with a capacity of 20 tons per hour when pulverizing to 80 per cent through 200 mesh. The pulverized coal is conveyed to two hoppers, from which it is weighed and pumped to the storage hoppers at the points of consumption. All valves in the delivery system are controlled electrically from a board in the pulverizing plant, and their operation is almost completely automatic. An electrically driven air compressor with a capacity of 500 cu.ft. per minute furnishes air for operation of the transportation lines.

Water for industrial use throughout the plant is pumped from Kelley Lake, about a mile distant, through a 12-in. line. Two motor-driven two-stage centrifugal pumps are used, each with a capacity of 1,000 g.p.m. against a 300-ft. head. Water for cooling the boshes at the casting wheels is pumped from a reservoir near the anode-casting building. This reservoir is 314x348x8 ft. deep and so large that no cooling sprays are required. As its elevation is lower than that of the boshes, the water returns by gravity. The bosh pump house contains three 5,000-g.p.m. electrically driven centrifugal pumps and a 500-gal. fire pump driven by a steam turbine for emergency use if the electric power should fail. All electrically driven pumps in the bosh pump house as well as at Kelley Lake are started and stopped by remote control from the refinery.

Most of the electric power comes from International Nickel's hydro-electric plants. It is received at the refinery at 30,000 volts, three-phase, 25 cycles, and stepped down to 2,300 volts in an outside substation containing four 2,000-kva. transformers.

The power house, situated at the west end of the machinery bay, contains three 2,000-kva. motor-generator sets, each made up of a 2,300-volt synchronous motor, two direct-current generators connected in parallel with rated capacities of 6,000 amperes at 160 volts, and an exciter. Two of the machines carry the entire load of the two electrolytic circuits; the third serves as a spare. Sufficient space has been allowed for installing two other machines of the same type.

Power is generated from the waste-heat boilers by a 2,500-kva. geared turbine-generator. This takes steam at 160 lb. and exhausts at 10 lb., the exhaust passing into the heating lines or to the atmosphere. An extra 1,000-hp. boiler is intended as an auxiliary to handle the heating load when the furnaces are not operating. All steam, however, is generated at 160 to 175 lb. and used for power as much as possible before it passes into the heating lines.

The turbine-generator is arranged so that it can operate either in synchronism with the Nickel company power or independently. In actual operation the load of the electrolytic division, which does not fluctuate greatly, is carried on purchased power and the light and power load on the turbine-generator. Power is distributed at 2,300 volts and is accurately measured by an integrating wattmeter on each circuit. Outside substations, near the departments served, step the voltage down to 550 volts for motors and 110 volts for lighting. Compressed air at 100 lb. for use throughout the plant is supplied by a 2,000-cu.ft. per minute compressor driven by a synchronous motor in the power house. The use of so many large synchronous motors makes it easy to maintain a unity power factor at all times. For handling equipment in the power house a 15-ton hand-operated overhead crane is used.

As the refinery is situated so far from the nearest large industrial center, it is necessary to be in a position to make any required repair quickly. A shop building 400 ft. long and 70 ft. wide has accordingly been erected containing woodworking, electrical, mechanical, pipe, structural-steel, and blacksmith shops, all equipped with the most modern types of machinery. The administration building and laboratory is a two-story brown-brick structure, with a poured gypsum slab roof similar to the roofs in the main buildings of the plant. All windows are double, and the building is amply insulated with 2-in. precast gypsum blocks.

THE HUNTINGTON ROLLING MILL

H. S. Arnold and A. S. Shoffstall

Manager of Production, and Manager of Huntington Works, respectively

INTERNATIONAL Nickel's rolling mill and refinery at Huntington, West Virginia, has been operating since June, 1922. From an original investment of $4,000,000, this plant now represents more than twice that amount in added buildings, equipment, and improvements. Before it was built, the requirements for our rolled products were met by arrangements with other rolling mills to produce from ingots supplied from the old refinery at Bayonne, New Jersey. At Huntington, the company produces Monel metal and malleable nickel, in the form of bars, rods, wire rods, wire, strip, and sheets and tubes of all ordinary dimensions. These products are thus under the control of the company in every detail from the crude ore to the finished material.

The plant at Huntington takes both nickel-copper matte from the Canadian smelter and electrolytic nickel cathodes from the Port Colborne refinery for its raw products; the one for the production of Monel metal, the other for pure malleable nickel and for special nickel alloys.

Matte for Monel metal contains about 25 per cent copper, 55 per cent nickel and 20 per cent sulphur. A large jaw crusher reduces it to egg size, after which it is ground in ball mills to 16 mesh, preparatory to dead-roasting. The four calciners for this work are 80 ft. long by 17 ft. wide, oil-fired, straight-line furnaces of modified Edwards type, with mechanical rabbles. The product, known as Monel oxide, is mixed with charcoal and drawn into tubs, covered, and allowed to cool. Then it is sent to the refinery melting furnaces, the charcoal amounting to about 25 per cent of the furnace charge.

In the refinery are two 20-ton open-hearth furnaces, one 10-ton open-hearth furnace, and two 3-ton open-hearths. There are also four electric arc furnaces of 12, 8, and 3 tons' and ½-ton capacity. Three are of the Moore type and one is a Heroult. The 12-ton furnace is the largest electric furnace in the world operating entirely on non-ferrous alloys.

The two large open-hearth furnaces are connected to waste-heat boilers, the steam being used by steam hammers and in the auxiliary power house. At the refinery, ingots are produced directly from the acid-lined open-hearth furnaces or from the basic-lined electric furnaces, or by a combination of both (duplexing).

Metallic charges only are handled by the electric furnaces—either pig or hot metal from the open hearth or cathode nickel for the production of malleable ingot. The standard ingot is 14 in. square and weighs rough about 1½ tons. To safeguard the finished product from surface defects, each ingot is milled on four sides to a depth of ¼ in. This is done on a battery of special milling machines, and afterward any small defects are chipped out by pneumatic chipping hammers.

The ingots then go directly to the hammer shop for forging or cogging to various sizes of blooms. Equipment here includes four steam hammers of 16,000, 10,000, 3,500, and 1,500 lb. There are five heating furnaces of the regenerative type, equipped with automatic air- and gas-regulating devices. Heating plays an extremely important part in the production of Monel metal and nickel; hence every precaution is taken here for careful control.

The rolling mills proper are divided into two departments, in separate buildings; the one consisting of merchant and wire-rod mills for the production of sheet bars, billets, rods of various sizes and shapes, and wire rod in coils; the other is a sheet mill for producing hot- and cold-rolled sheets.

Monel metal and nickel are extremely tough and tend to cool rapidly; hence it is necessary to have mills of great strength and rigidity.

The forged ingot or bloom from the hammer shop, after being inspected and overhauled to remove scale and surface imperfections, is delivered to a 24-in. sheet-bar mill. This mill consists of two stands, one stand three-high and the other, the bullhead, two-high. The blooms are handled between furnace and rolls by a Brosius charger. Sheet bars and rod billets are cut while hot, either by a heavy shear or hot saw.

Exceptionally heavy construction has been employed in the sheet mills themselves. Here, the roll diameters are 30 in. and the maximum sheet width is 60 in. The roughing rolls are balanced and driven by fully inclosed cut gears, giving a smooth roll movement and reducing the tendency to chatter with consequent marking of the rolled sheet. The main motor drive is a 1,200-hp. motor, with two 10-ton flywheels running at the motor speed of 10,000 ft. per minute.

Mill equipment is similar to that usually found in sheet mills. The natural-gas-fired annealing furnace is of the continuous type, designed by the Surface Combustion Company. It is 170 ft. long and will handle sheets up to 60 in. wide. Another special annealing furnace of original design is just being completed. This furnace is electrically heated, continuous in operation, and capable of maintaining a hydrogen-gas atmosphere within the furnace.

As a part of the sheet-mill equipment there are also four stands of two-high cold-roll mills, 26 in. in diameter, capable of rolling sheets up to 48 in. wide; two sets of Bliss cluster mills with 12-in. working rolls, handling sheets up to 36 in. wide; and a Schmitz four-high mill, rolling up to 48 in. wide. The Bliss mills and the Schmitz mill are equipped with roller bearings. The sheet mill receives sheet bars from the bar mill, hot-rolls them to various gages of sheet, pickles and anneals this sheet,

gives two passes in the cold mill, re-anneals, and stretcher levels. This product is a so-called full-finished sheet. Cold-rolled sheet is produced from the hot-rolled product by reducing the gage at least 20 per cent in the cold mills.

Full-finished sheets are always in the annealed condition when marketed. Cold-rolled sheets may be finished to various tempers from soft to hard. Monel metal full-finished sheets are sometimes given a pleasing appearance by a grinding and polishing procedure called a No. 8 finish. Cold-rolled sheets are also polished, the standard being a mirror finish, so-called No. 5.

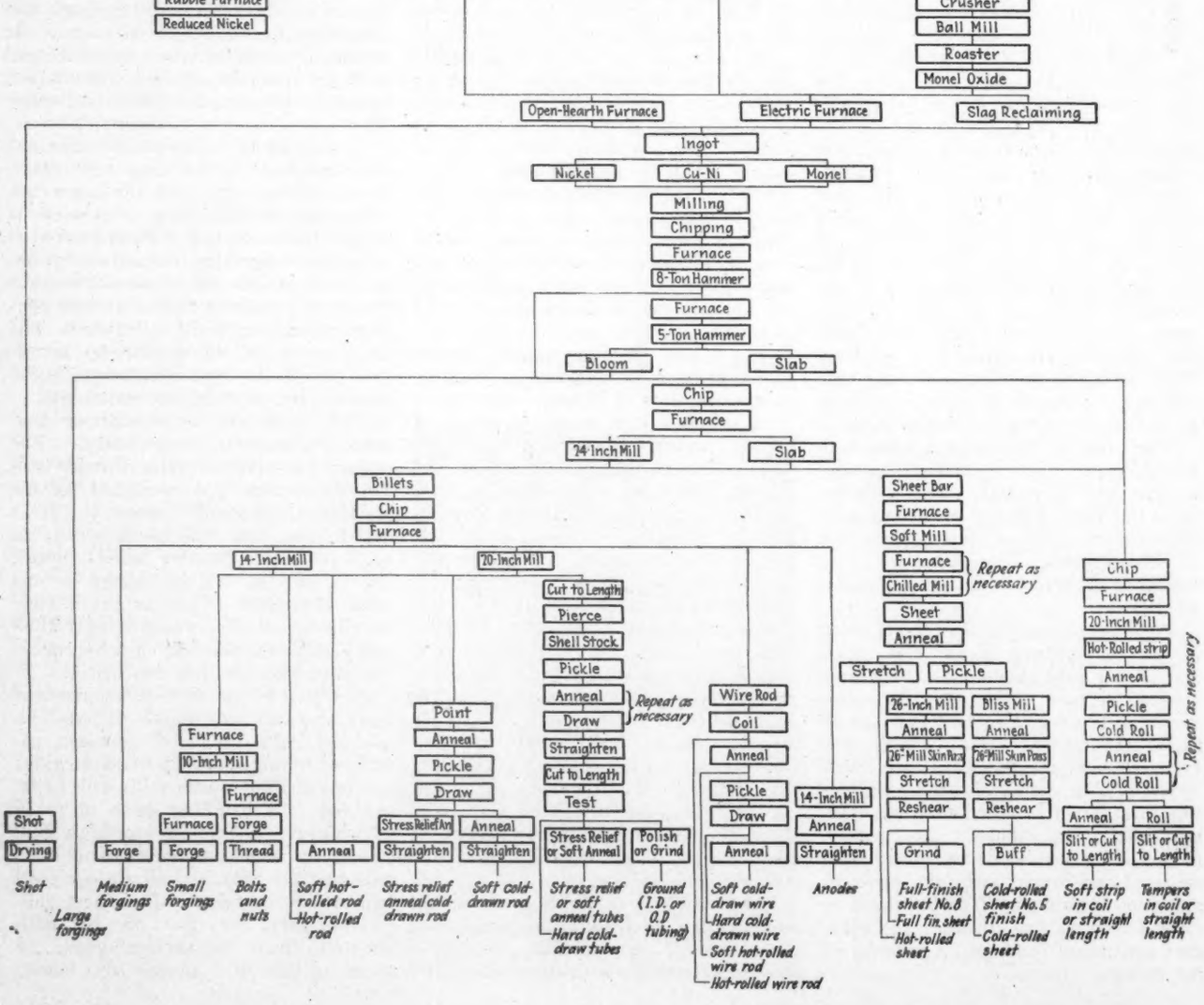
In the same building with the 24-in. merchant mill, are five other mills, a 20-, 14-, and a 10-in. mill, a 14-in. Belgian rougher, and a wire mill. The last-named consists of two separate mills in line, one a five-stand roughing mill, the other a four-stand finishing mill. Both are 9-in. pitch diameter. All of the merchant mills with the exception of the wire-finishing mill are so-called slow-speed mills, slow speed being advisable for nickel alloys.

The 24-in. merchant mill prepares billets for further rolling in the smaller merchant mills. Rods and bars from 4 in. round or square down to $\frac{3}{32}$ in. in diameter are produced. Flat bars and coiled strip are also made, ranging from $\frac{1}{2}$ in. wide by $\frac{1}{8}$ in. thick up to 8 in. wide by 2 in. thick. Strip up to about 20 in. wide can be produced, in the lighter gages. All of the products from the merchant mills have the black oxide finish typical of hot-rolled nickel-copper alloys.

The cold-drawn department has for some time been an integral part of the Huntington operations, but recently it has been rebuilt and greatly enlarged. This department produces cold-drawn rods, tubes, and wire and a miscellaneous variety of cold-drawn shapes. It includes a complete tool room with necessary machinery for the cutting, grinding, and storage of all dies and a Hump treatment electric furnace for the hardening of the tools. Chromium-plating of the dies and mandrels has been found advantageous, so a complete chromium-plating unit is installed next to, but separate from, the tool room. Inside the building proper a smaller building houses pickling equipment. Here, tanks are constructed of reinforced concrete and lined with acid-proof brick, great care being taken in their construction, as they must hold an extremely corrosive liquid comprised of a mixture of sodium nitrate, chloride, and sulphuric acid. This solution is maintained at a temperature of 190 deg. F. by the use of live steam, which also acts as an agitator.

Space forbids even a brief description of many of the cold-drawing and hot-rolling operations; of the manufacture of tubes; and of many other activities, some idea of which may be obtained from an inspection of the flow sheet below.

Flow sheet of Huntington plant



ENGLISH OPERATIONS OF THE MOND COMPANY

—The Mond Staff

THE MOND Nickel Company, Limited, now a subsidiary of International Nickel, was incorporated in Great Britain in 1900 to produce nickel by the process invented by the late Dr. Ludwig Mond in collaboration with his assistants Dr. Carl Langer and Dr. H. Hartz. Its operations are now carried on only in Great Britain in the works to be described.

Clydach Nickel Refinery

The Clydach (Wales) Nickel Refinery has grown from a modest plant with a capacity of about 500 tons of nickel per year in 1902. It is situated in Clydach, Glamorganshire, about 9 miles from Swansea. The works were designed to use bessemer matte as raw material, the copper being produced as bluestone. However, as the present raw material is washed nickel sulphide from the Port Colborne works, in Ontario, the bluestone plant will be referred to only briefly.

In general, the buildings and plant include: (a) receiving, milling, and calcining department housed in three buildings; (b) leaching and bluestone making, housed in five buildings situated between and connected to (c) the nickel extraction plants, whereof six are connected to the bluestone plants and a seventh building stands apart from the others. A nickel-salts plant is adjacent to one of the bluestone plants, and there is a concentrate plant for precious-metal residues, a producer-gas and water-gas plant, a smelting department to deal with intermediates, repair shops, warehouses, office, and a laboratory.

THE nickel sulphide as received from Canada contains 3 to 4 per cent moisture, so it is first dried in one of two gas-fired dryers formerly used in the leaching department. These consist of a hard-lead shell, housing a rotating shaft on which is mounted hard-lead circular shelves, two 8 ft. and two 9 ft. in diameter. As the shelves rotate, screw conveyors move the material over the shelves, which, being heated by gas flames, dry the material rapidly.

Dried sulphide is conveyed to the Krupp ball mills serving the calciners, where it is further ground through 60-mesh screens. A separate ball mill is provided for each of the eighteen calciners, which are of straight-line double-deck type. Each hearth is 78 ft. long by 8 ft. wide. The sulphide is stirred and pushed along by multi-blade plows rotated by pinions engaging in a rack as they are circulated by an endless chain. Eight plows are attached to each chain and each passes through the furnace every six to seven minutes. The material takes about twelve hours to pass through the furnace. There is about 8 lb. per square foot of hearth area, and each furnace calcines 7 to 8 tons per day, reducing the sulphur from about 23 to about 1.5 per cent.

Producer-gas firing is used, there being twelve burners on each hearth. Gas consumption is about 25,000 cu.ft. per hour. Temperatures vary from atmospheric to about 780 deg. C.

DRAFT is induced by electrically driven fans. Waste gases pass through a dust catcher and a coke filter and thence through the fan to the flue leading to the three brick stacks, 10 ft. in diameter by 150 ft. high.

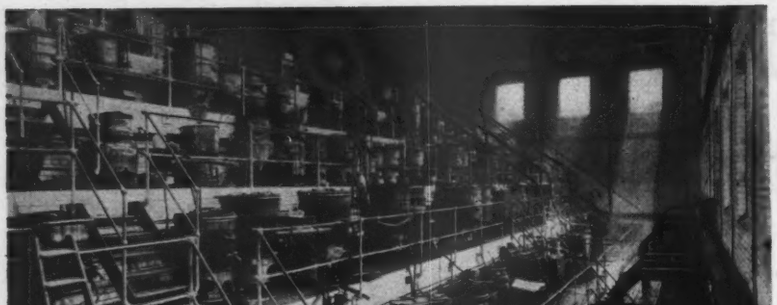
The calcine is conveyed to the nickel plants in tip cars drawn by gasoline locomotives. Formerly, when treating bessemer matte, the calcine was moved by screw conveyors and elevators to the leaching apparatus, where copper sulphate was formed by treatment with hot dilute acid. The solution so made was quickly cooled to crystallize out fine meal crystals of bluestone, which were then recrystallized for market.

The operations in the nickel plants are those peculiar to the Mond process of volatilizing the nickel in the form of carbonyl. Plant design presented interesting problems: Many tons of powdered solid had to be treated several times alternately in two separate gas systems at considerably different temperatures; furthermore, atmospheric oxygen must be excluded, and, owing to its poisonous character, none of the gas used could be permitted to escape from the system into the building. Whereas in one gas system the gas was to be used in reactions that consumed it, and the residuum was of no further use in the process, in the other system the gas was to be employed in a cyclic process, wherein its chief component alternately entered into combination with and was dissociated from a component of the powdered solid, the two reactions taking place in different apparatus and at different temperatures. The swift increase in the rate of dissociation with increase of temperature of nickel carbonyl, with the consequent deposition of metallic nickel on any solids with which it might be in contact, indicated alike the troubles that might arise from ill-considered design, and the method by which this property could be used to produce the nickel in the form required for use by various industries.

REDUCTION of the oxides is accomplished by heating to 330 to 350 deg. C. with water gas in "reducers." These are cast-iron towers built up of 21 sections, each of which sections is a flanged cylinder 6 ft. diameter and about 19½ in. high. In the lower part is cored out a heating chamber having rectangular inlet and outlet pipes with their axes parallel. A radial septum located between the two openings compels the heating gases to travel all over the heating chamber. In the center of the bottom is a circular drop hole about 22 in. in diameter, which also accommodates the central shaft. About midway between the top of the heating chamber and the top of the section is the inner shelf, 5 ft. 2 in. in diameter, with a central hole 9 in. in diameter. It is supported by six lugs resting in recesses cast in the section wall. The sections are bolted together gas-tight. The central shaft, extending from the drive gear in the base to the top of the structure, carries at each shelf a cast-iron boss equipped with three stirrer arms each with five or six scraper blades. These stir and move the material on the shelves just as is done in a McDougall roaster.

Matte is fed on the top shelf through a cast-iron rotary valve which, while freely admitting the solid material, minimizes the escape of gas. It consists of a fluted conical plug rotating within a cast-iron housing between the matte screw conveyor and the reducer feed pipe.

Necessary heating is accomplished by burning producer gas in a brick tower adjacent to the reducer. There are two flues, each as long as the reducer is high. In one of these the gas is burned near the bottom and the hot gases enter each of the sections through the heating-



In the Acton plant

gas inlets. The other, or off-take flue, serves to take away the gases to the main flue after they have traversed the heating chambers.

A definite separation of the heating gas on the one hand, and the water gas and solid material undergoing reduction on the other, is thus secured. The water gas is introduced at the top section and leaves at the next to the lowest. It thus travels concurrently with the solid material, which is necessitated by the high water content of the gas after reduction of the oxides. The water would condense in the rotary valves and cake up the material in them and in the conveyors. To conserve heat the sections are lagged with mineral wool.

The off-take gas, after removing the water vapor in scrubbers, contains about 11.2 per cent carbon dioxide, 72.4 per cent carbon monoxide, 12.3 per cent hydrogen, and 4.1 per cent nitrogen. It is used in part to replenish the "plant gas" circulating in the volatilizers and decomposers, and in part is burned in the various gas burners along with producer gas.

THE formation of nickel carbonyl by interaction of carbon monoxide and metallic nickel takes place in "volatilizers" which resemble the reducers. As the reaction generates heat, there are no heating chambers, so the sections are only 15 in. high. There are 27 of them in each volatilizer. Rotary valves are not used, and the gas enters at the bottom and is taken off at the top. Great care must be taken that no gas leaks whatever occur at the joints or elsewhere, and search for possible leaks is made several times each day.

The gas off-take pipe leads to a gas filter, where any metallic dust is filtered out of the gas in woolen bags, and thence to the top carbonyl main. This is connected to a motor-driven gas blower with a capacity of about 6,000 cu.m. of gas per hour, which pumps the gas through the decomposers.

To get rid of the heat generated by the reactions, the iron surfaces of the volatilizer are cooled with flowing water. The "plant gas" entering the volatilizers ordinarily analyses about 70 to 72 per cent carbon monoxide and on leaving contains from 10 to 120 grams nickel per cubic meter, depending on the greater or less degree of exhaustion of the nickel in the material under treatment. Some plant gas always leaks from the volatilizers to the reducers, which loss is made up by continuously pumping back a small proportion of dehydrated reducer end-gas.

The carbonyl-laden gas from the blower reaches the decomposers via the lower carbonyl main. These decomposers are made up of a cast-iron base about 5 ft. 10 in. high, upon which are erected, one above the other, six decomposer boxes also of cast iron. The boxes are each 2 ft. 7 in. high by 2 ft. 2½ in. in diameter at the top, tapering to 1 ft. 9½ in. at the bottom. Each has a gas ring carrying 24 tubular, side-jet burners burning producer gas. The bottom box has a conical bottom piece, below which is a rotating drum for regulating the rate of discharge of pellets from the lower box. The decomposer holds 9 to 10 tons of pellets, which are kept circulating through the decomposer by the drum and a chain-and-bucket elevator housed in a cast-iron shaft alongside the decomposer.

As the pellets increase in volume, some of them, corresponding to the current make, overflow the top box through a pipe to a box in the base. They are removed thence by blowing out the plant gas from the base with "inert gas"—mostly carbon dioxide and nitrogen—and withdrawing the box.

The carbonyl-laden gas enters through a central vertical pipe which passes through the structure and has shielded openings in each box through which the gas flows and diffuses through the mass of hot pellets on its way to the outlet rings. As the pellets are kept at about 180 deg. C., nearly all of the carbonyl is decomposed, leaving its nickel component as a very thin plating on the surface of the pellets. The off-take gas returns to the volatilizers.

VARIOUS units comprising the apparatus are assembled in each nickel plant and connected by gas-tight elevators, screw conveyors, and gas mains, so as to make a self-contained system. The newest plant has, first, five reducers, then six volatilizers, then two reducers, four volatilizers, two reducers, and finally three volatilizers. Such a plant can produce over 25,000 lb. of nickel pellets per day.

The nickel pellets are screened, the small ones are returned to the decomposers via a gas lock, and those from about $\frac{1}{16}$ to $\frac{1}{4}$ in. in diameter are packed either in steel drums or wooden kegs holding about 550 lb. for shipment to market.

In its travels through the nickel plant, about 80 per cent of the nickel content of the calcined sulphide is extracted. The residue is discharged from the last volatilizer through a gas-heated conveyor to decompose any entrained carbonyl, and is then returned to calciners set apart for dealing with such "concentrate." The calcine is then passed through a nickel plant again, the residue called Concentrate II going to the concentrate plant. Here nickel and copper are removed by acid treatment, leaving a residue containing platinum-group metals, which is shipped to the platinum refinery at Acton.

The gas plant includes 32 hand-poked producers using local anthracite with air saturated with water vapor at 60 deg. C. The coal is very low in ash, and about 150,000 cu.ft. of gas is made per 2,000 lb. of coal. Average analysis is about 5.6 per cent carbon dioxide; 24 per cent carbon monoxide; 20.5 per cent hydrogen; 1.5 per cent methane, and 48.4 per cent nitrogen.

IN this plant are twelve water-gas generators, with the usual superheaters. An excellent quality of Welsh anthracite is used. An unusual feature of operation are the long air and steam blows (ten minutes). The valves are interlocked but are manually operated. About 50,000 cu.ft. of water gas is made per 2,000 lb. of coal, and its average analysis is about 3.8 per cent carbon dioxide; 36.0 per cent carbon monoxide; 57.3 per cent hydrogen; 1.2 per cent methane, and 1.7 per cent nitrogen. Anthracite is obtained from the mines of the company's subsidiary, the Tareni Colliery Company, at Pontadawe.

For smelting intermediates there are four small oil-fired reverberatory furnaces, of which probably only one furnace will be used when the plant is dealing solely with washed sulphide. A small cupola furnace is used also to clean up the rather sticky reverberatory slags.

All International Nickel's Precious Metals Refined at the Acton Plant

THE Acton precious-metals refinery, situated in a London suburb, recovers in a refined state the precious-metal content of concentrates produced at both the Clydach and Port Colborne nickel refineries. It is now the largest platinum refinery in the world, the enlargements effected this year having raised its yearly capacity to at least 300,000 oz. of platinum-group metals. The plant is thus prepared to refine platinum from other sources on a custom basis.

Necessarily, the process is an intricate one, as seven metals—platinum, palladium, rhodium, ruthenium, iridium, gold, and silver—are to be separated not only from one another but from a gross assortment of other substances contained in the raw material. Long and painstaking study and research have developed the process as now used to a degree of perfection that is indicated by the high purity of its products as shown in the following average analyses over many months: platinum, 99.93 per cent; palladium, 99.94; rhodium, 99.76; ruthenium, 99.72; iridium, 99.68; gold, 99.97; and silver, 99.97 per cent. These figures give point to the statement that the plant actually is a chemical laboratory on a large scale.

Acton refinery's place in the economic structure of the platinum market is unique, for, unlike the other platinum refineries, it is dealing with concentrates which are a byproduct of ores which are primarily worked for the recovery of other metals. Therefore the mining and treatment costs up to the refining stage may be considered as having been absorbed in the cost of producing nickel and copper. The process developed at Acton is highly efficient and operates at a low cost.

By the middle of 1930 the annual rate of production was as stated in the table, and it is steadily increasing. Further production from the Frood mine will materially increase the amounts of precious metals produced.

Production of Precious Metals

	Troy Ounces
Platinum	50,000
Palladium	26,000
Rhodium	3,300
Ruthenium	700
Iridium	500
Gold	4,800
Silver	96,000

Concentrates from Port Colborne contain from 45 to 60 per cent of platinum metals; those from Clydach about 4 per cent, with considerable lead and silver. As Clydach is now dealing with washed sulphide from Port Colborne instead of bessemer matte, its concentrate will in future contain less lead and silver and much more platinum metals.

A furnace department and a wet process department are included in the Acton refinery. In the first, the Clydach concentrate is as a primary operation smelted with litharge and soda ash in one of two small oil-fired reverberatories of 224-lb. capacity each. The roofs are of high-alumina blocks and the hearths of magnesite bricks and Marborite. Slag from these furnaces containing some precious metals is sent to Clydach for re-treatment. The lead ingots produced are cupelled in one of two tilting gas-fired cupels with a capacity of 224 lb. of lead each. All gases and fumes from reverberatory and cupel furnaces are drawn by fans from the furnaces and blown into scrubber towers, where they are completely freed from fume and dust before they are discharged into the atmosphere. There are two small 500-cu.ft. per minute rotary compressors to blow air for the cupels. The product of the cupels is about four times as rich in precious metals as the concentrate, and is granulated by pouring in water to form "P M Grain No. 1." In this department there are also three gas-fired tilting crucible furnaces used to reduce silver chloride and melt the silver, as well as other small furnaces for dealing with intermediates.

The wet process, which deals with the "P M Grain No. 1" as well as with the Port Colborne concentrate directly, is housed in a building wherein the various pieces of apparatus are assembled on a step-like structure of six levels. Floors and walls are covered with smooth acid-proof materials and exacting standards of neatness and cleanliness are enforced. The initial operations are carried out on the top level, and so far as possible successive operations are performed on the next succeeding levels, thus using gravity flow (see illustration on p. 496).

"P M Grain No. 1" is first treated with hot sulphuric acid to dissolve silver with a part of the palladium. From the solution, silver is precipitated as chloride, which is sent to the furnace department to be reduced and the silver cast as anodes, about 13 in. square and weighing about 960 oz., for electrolytic refining. Palladium is precipitated from the silver chloride filtrate as palladous-amino-chloride, which is purified by dissolution and reprecipitation. The pure salt is afterward ignited to form palladium sponge.

Port Colborne concentrate and the insoluble residue from the sulphuric-acid treatment is heated with aqua regia to dissolve platinum, palladium, and gold. The resulting solution is first treated to precipitate gold, which is melted and cast as anodes weighing about 100 oz. for electrolytic refining. Palladium is precipitated and purified as described in the foregoing, and platinum is next precipitated as platinic-ammonium-chloride, which, after being purified, is ignited and yields pure platinum sponge. All end liquors from the foregoing operations are led to cementation tanks, where any precious metals therein are recovered as a sludge for further treatment. The sludge and the insoluble from the aqua regia treatment already mentioned goes to the furnace room, where it is smelted to form "P M Alloy No. 2," containing rhodium, ruthenium, and iridium, which are subsequently separated and produced as metallic sponge.

Most of the apparatus used is salt-glazed earthenware, the capacities ranging up to 100 gal. Fused silica ware in sizes up to 40-gal. stills, with silica condensing coils and 5-gal. silica basins, are also used. Dissolver jackets, stands, and tilting gear are of cast iron. Two ½-ton overhead bridge cranes of 41-ft. span can reach all parts of the working floors. The space under the step-like structure is used in part for shops and scrubber rooms, and in part for storing valuable materials.

Adjacent to the wet-process plant is the ignition room, where the various products are ignited to produce metallic sponge. Here are large gas-fired muffle furnaces and iron working tables, where the preparation of the furnace batches and other work is performed.

Hydrochloric-acid storage tanks are of wood lined with acid-resisting rubber. Wooden reduction or cementation tanks are lined with lead or Nordac.

Process steam is supplied from a 150-hp. automatic gas-fired boiler and from a 200-hp. oil-fired marine-type boiler. Two 6-hp. motor-driven air compressors supply air for blow cases and two 17-hp. vacuum pumps serve the filters. Electrical energy is used for power, the supply being delivered as three-phase, 50-cycle, 415-volt current. A load of 65 kva., maximum demand, is converted to 415 volts, d.c., by a 150-kw. rotary converter.

ROLLING of non-ferrous nickel alloys in England is carried out in Birmingham by Henry Wiggin & Company, Limited.

The plants are in operation at both ends of Wiggin St. There are also two other outlying works, one in Victoria St., Smethwick, where cobalt preparations and tin oxides are made, and the Globe Works, in Newtownrow. The company's production now includes nickel-copper alloys in the form of wire, sheet, rod, and other mill forms, one of the latest products being the 45:55 nickel-copper alloy known as Silveroid, which is used for food-service equipment, architectural metal work, and various other purposes.

Another of the subsidiaries of the parent company in England is Birmingham Electric Furnaces, Limited, a company which produces furnaces for heat-treatment plants and enjoys an extensive business throughout the British Isles.

NEWS OF THE INDUSTRY

Explore Complex Tokatea Lode in New Zealand

Prospecting of the extensive complex Tokatea lode, near Coromandel, Auckland Province, New Zealand, has indicated an orebody varying from 14 to 125 ft. in width. Assays are reported to yield 16 to 18 per cent lead, up to 14 per cent zinc, 2 to 7 oz. of silver, and 3 to 14 dwt. of gold per ton. A considerable portion of the material can be mined by open cutting. Flotation experiments have been begun with the object of obtaining lead, zinc, and pyrite concentrates. Manufacture of superphosphate fertilizer is considered a possibility. Lack of capital is said to be the greatest difficulty. Mount Tokatea Mineral Fertilizer is the name of the operating company.

■

Morenci Pilot Plant Started

Operation of the pilot plant built at its Morenci branch, in Arizona, by Phelps Dodge Corporation, for the purpose of testing methods of treating its low-grade Clay orebody, was started at the end of October. The plant comprises a 100-ton section for the testing of milling methods and a 50-ton section for experimenting with leaching methods. The Clay orebody contains more than 245,000,000 tons of copper ore, averaging better than 1 per cent copper, which can be mined through tunnels and which, the company believes, can be converted into metal at a comparatively low cost. The plant that will eventually be erected to treat this material will have a capacity of about 25,000 tons daily.

■

Coppermines Appeals Case

Consolidated Coppermines has appealed to the U. S. Circuit Court of Appeals from the decision made by Judge F. H. Norcross, of the Nevada district court, in the injunction suit brought by Nevada Consolidated against Coppermines to prevent mining of ore at the western end of the Liberty pit, Ely, Nev., in which both companies have interests. Hearing of several counterclaims made by Coppermines, on which judgment was reserved by Judge Norcross, will be held in February, 1931.

■

Ontario Refining Starts New Unit

Ontario Refining has put in operation the new silver- and precious-metal-refining unit at Sudbury, Ont., which was built in conjunction with its custom copper refinery. The unit will handle slime containing precious metals precipitated in the electrolytic refining of International Nickel and Granby Consolidated blister copper. The first charge consisted of a part of an accumulation of slime resulting from the refinery's operations since July. An acid plant is also being built in connection with the refinery. It will retreat the acid from the electrolytic tank house and recover the nickel in solution. The nickel residues will be returned to International Nickel.

■

Copper Range Cuts Wages

A reduction in wages and salaries of 7½ to 10 per cent has been announced by Copper Range, operating near Painesdale, Mich. The reduction is effective Nov. 1. The company is maintaining production at the Champion mine at about 1,800,000 lb. of copper monthly, although employing 130 fewer men than usual.

■

Tybo Cuts Ore at 800 Ft.

Crosscutting on the 800 level of the Tybo lead-zinc mine of Treadwell Yukon, at Tybo, Nev., had penetrated the vein for 25 ft. on Oct. 31, with the face still in ore, according to W. H. Blackburn, general manager of the property. Of this, the last 20 ft. was good mill-grade ore. On the 700 level, the deepest point to which development had been previously carried, the ore was 30 ft. wide.

■

Commerce Ships From See Sah

Resumption of milling operations by Commerce Mining & Royalty at the Jaybird mill, on the See Sah allotment, in the Tri-State district, late in October, is expected to offset most of the drop in zinc concentrate production resulting from suspension at the Missouri-Kansas properties in the Waco area. Four small mills have also been started that may cover or exceed the temporarily lowered output—more than 350 tons of concentrate weekly. Total Tri-State output is now about 9,500 tons of zinc concentrate weekly.

■

Dome Starts New Mill

Operation of its new 1,500-ton mill at Porcupine, Ont., was started by Dome Mines on Oct. 28. The plant, of wooden construction, replaces one of similar capacity burned a year ago. Ore reserves for about four years of operation are available in the mine, and profits are expected to be almost $2,000,000 annually. The new plant will use cyanidation only for the recovery of gold, although the old plant also used amalgamation.

Anaconda and Inco Announce Further Cuts in Output

Anaconda Copper and International Nickel, leading factors in the base-metal industries, have taken additional steps toward curtailing production because of the current market depression. Anaconda is closing the zinc concentrator at Anaconda, Mont., and International Nickel is curtailing mine tonnages from its properties at Sudbury, Ont. The curtailment at Sudbury will involve the discharge of about 600 men.

Capacity of the Anaconda zinc concentrator is about 1,500 tons of ore daily. The ore comes largely from the Butte mines and includes some custom material, notably from Butte & Superior. A byproduct lead concentrate for shipment to East Helena is made, but the chief product is zinc concentrate for the company's electrolytic plants at Anaconda and Great Falls. Because of the large stockpiles of concentrate at these two units, closing of the concentrator need not necessarily mean any further cut in actual metal production within the near future.

At Sudbury, the daily tonnage from the Frood is being cut to 3,000 from about 4,000 tons daily, and further reductions will also be made at Creighton, which has been producing about 1,700 tons daily. One of the four reverberatory furnaces in operation at the Copper Cliff smelter will be closed. Construction work on the No. 1 refinery unit, which is being moved to Copper Cliff, will continue. The dismissal of 600 men will bring the operating force at Sudbury down to 5,000.

Falconbridge Nickel, the only other company producing nickel and copper in the Sudbury district, has suspended smelting operations for two months. Production of matte by the plant which had been running at its capacity of 300 tons daily, was too great to be handled by the company's small refinery in Norway, resulting in an accumulation of a comparatively large stockpile. The suspension of operations will permit working off this stockpile. It will, in addition, permit necessary construction work, preparatory to doubling smelter capacity. The refinery will probably be enlarged also.

■

Montana Power Gets Franchise

Freeholders of the cities of Butte and Anaconda, Mont., have voted to grant a natural-gas franchise to Montana Power. This company is also asking for a franchise in Livingston, Bozeman, and Deer Lodge, and already has a franchise in Helena. Cost of installing equipment to furnish these cities with natural gas is estimated at between $12,000,000 and $15,000,000. Substitution of natural gas for coal dust and oil as fuel in smelting at the Anaconda plants will result, with consequent economies in the cost of producing Butte Copper.

EXCLUSIVE

CABLES

FROM CORRESPONDENTS IN THE PRINCIPAL MINING CENTERS

Rand Output in Nine Months 2 Per Cent Above 1929

Johannesburg, Sept. 29.—Official statistics for gold production from the Witwatersrand show an output, during the first nine months, of 7,658,207 oz. of gold, compared with 7,496,317 oz. of gold in the first nine months of 1929. This is an increase of 161,890 oz., or more than 2 per cent. Profits are up also. On the basis of official company estimates, an increase of £250,000 over last year's earnings has already been recorded. A clean-up at the Village Deep plant, recently acquired by Robinson Deep, has yielded a recovery of £125,000.

. . . . An influential company is now exploring a promising alluvial gold occurrence recently found at Steynsdorp, in Swaziland. Hydraulicking methods are being used. Consolidated Mining & Smelting, of Canada, has been officially granted a five-year concession to prospect a large mineral area in Southwest Africa. As previously reported, engineers are now on the way to prospect the field.

■

Suggest New Restriction Plan at Malay Tin Meeting

London, Oct. 31—At a meeting of the Tin Producers' Association at Ipoh, Federated Malay States, discussion of a restriction scheme, prepared by J. Lovett, of the Malayan Mines Department, has been held. Mr. Lovett suggests creation of a fund of £1,500,000, presumably by the low-cost tin mines, with the object of raising the price of the metal to £200 per long ton. The scheme is generally regarded as impracticable in London. Gopeng, Tekka, Pahang, Petaling, and other of the low-cost Eastern producers are still paying regular dividends.

. . . . Mond Nickel, British subsidiary of International Nickel, denies rumors of a reduction in the price of nickel. The company intends to maintain the quotation at £170 a ton, fixed since 1925. British Aluminum is increasing its capital by adding 900,000 preference shares. The money will be used to redeem 500,000 shares of debentures and to increase the plant capacity.

. . . . At the annual meeting of Russo-Asiatic Consolidated, Leslie Urquhart, the chairman, stated that for a fair settlement of the company's claims a change in the Russian economic system was necessary. In the meanwhile, through Mining Trust, its affiliated holding company, the Mount Isa property, in Queensland, had been developed into the largest silver-lead-zinc mine in the world. He also referred to the interests that Mining Trust holds in the Villemagne property, in France, and New Guinea Gold.

. . . . West Mexican Mines, which operates silver-gold properties in Chihuahua, proposes to reduce its capital by changing the 550,000 outstanding £1 shares to 2s. par and creating 4,950,000 additional shares of the same par. The rights of the "A" and "B" shares, also 2s. par, will be extinguished and a new issue of 10 per cent debenture stock will replace the existing debentures.

. . . . Payment of the half-yearly preference dividend of Premier (Transvaal) Diamond, which is usually declared on Oct. 31, has been postponed.

■

Most Equipment Installed at Wiluna Gold Property

Kalgoorlie, Western Australia, Oct. 29.—More than three-quarters of the machinery has now been installed at the Wiluna Gold property, near Meekatharra, which is scheduled to start operations about the beginning of 1931, on a scale of 40,000 tons of 35s. ore monthly. The new headframe on the main shaft will be in operation by the end of November, according to present expectations. At Geraldton, on the coast, the old storage tanks, with a capacity of 2,300,000 gal. of oil for the Diesel plant at the mine, have been completed.

. . . . An alluvial find at Larkinville, in Coolgardia, has yielded several large nuggets. More than £500 in gold has been recovered in a fortnight from one small area. At Kalgoorlie, the station has been cut on 1,200 level of the Croesus shaft, now operated by South Kalgurli, and crosscutting for the downward extension of the lode has been started.

■

Profits of North Broken Hill and Electrolytic Zinc Drop

Melbourne, Nov. 3. — Annual reports have just been issued by North Broken Hill and Electrolytic Zinc for the fiscal year ended June 30, 1930. Both companies, because of the drop in metal prices, show smaller net profits. North Broken Hill treated 452,295 long tons of ore, producing 94,330 tons of lead concentrate and 75,910 tons of zinc concentrate, all increases over the previous year. Net profit was £260,395, including £147,052 from investments, compared with £478,378 in the previous year. Ore reserves increased 200,000 long tons to 4,200,000.

. . . . Electrolytic Zinc produced 54,150 long tons of zinc, 218 tons of cadmium, and 24,163 tons of superphosphate at a net profit of £283,015 in the same period. In the previous year, net profit was £367,918. The company has suspended work on extensions to its electrolytic zinc plant at Risdon—which was being increased to a capacity of 70,000 tons annually—and has ceased all operation at its Rosebery unit, where a new mill has recently been built. It has on hand stocks of unsold zinc valued at £400,000.

. . . . Broken Hill South and Zinc Corporation, operating in the Broken Hill district, have put all surface labor and mechanics at their properties on part time because of the continued low metal prices.

. . . . A lead-silver lode has been found at Gayndah, 14 miles from Mount Isa, in Queensland. An English group has applied for a concession of 70,000 acres in the Hodgkinson and Georgetown mining districts of Queensland. Another lead-silver discovery has been reported at Nambucca Heads, in New South Wales. Its strike has been proved for 1,200 ft.

. . . . During the quarter ended Sept. 30, Mount Lyell Mining & Railway, in Tasmania, treated 64,283 long tons of ore, and produced 2,901 tons of electrolytic copper, 53,401 oz. of silver, and 1,033 oz. of gold, all increases over the previous quarter.

■

Work on N'Changa-Border Area Preparing for Construction

London, Nov. 1—Up to the present, Rhodesian Congo Border Concession and N'Changa Copper, which are developing a high-grade copper deposit near the N'Kana Concession, in Northern Rhodesia, have confind their activities largely to development and exploration work. Reports for the quarter ended Sept. 30, however, indicate that increased attention is being given to construction. The railroad extension to the property is now nearly completely graded, and a new power plant is being built at R.C.B.C.'s West Extension property. The three shafts have reached depths of 417, 72, and 469 ft. Ten drill holes are being put down, seven on R.C.B.C. and three on N'Changa ground. Geological work and prospecting throughout the entire concession area is being continued.

. . . . Rhodesian Selection Trust has 6.4 ft. of ore averaging 4.32 per cent copper in its drill hole No. 3 at the Mokambo North area. The ore was cut at 269 ft. Mokambo North lies to the east of Mulfulira, on the Belgian Congo border.

. . . . Production of Luiri Gold, in Northern Rhodesia, was only £2,021 from treatment of 1,607 tons of ore in September, indicating a further drop in grade, although the tonnage handled was normal.

. . . . Trepca Mines, in Yugoslavia, reports production of 2,229 tons of lead concentrate, averaging 70 per cent lead and 24 oz. of silver to the ton, and 1,003 tons of zinc concentrate, averaging 47.6 per cent zinc, in the period from Aug. 20, when operation of its new 500-ton plant started, to Sept. 30. Since the middle of September, the plant has maintained recoveries of 95 per cent of the lead content and 85 per cent of the zinc content. During September, the company drove 1,143 m. of openings, including 758 ft. on the new deep adit.

■

Metallgesellschaft Closing Berzelius Zinc Plant

Berlin, Oct. 31.—Metallgesellschaft is closing its Berzelius zinc smelters because of the low price of zinc. The plants have a capacity of about 28,000 metric tons of metal annually. Their closing, together with suspension of the Stolberg smelters, will substantially reduce Germany's production and make the proportion of zinc that has to be imported to meet consumption even higher than before. The fate of the zinc cartel in the long run is still regarded somewhat skeptically, largely because of the attitude of the producers overseas, but some hope is held for effective curtailment in the immediate future.

. . . . Rumors that an electrolytic copper refinery, with a capacity of 20,000 to 30,000 tons of copper annually, would be built in France by Trefileries du Havre, in conjunction with American Smelting & Refining, have been denied by the latter company, but they have evidently been accepted as true in some quarters. Electro-Metallurgie de Dives, the only copper refinery now in operation in France, which has a capacity of about 20,000 tons annually, has absorbed the Compagnie Générale de Mines et d'Electro-Metallurgie, which has substantial interests in several small European copper mines. Dives has an interest in the Scandinavian copper fields of Sulitelma and Skelleftea.

. . . . The results of the conference of international copper producers now being held in New York are eagerly awaited here. General sentiment is pretty optimistic. Traders are inclined to feel that the lowest prices have been reached and that copper buying will again be buoyant. Even the recent ending of the big strike in the Berlin metal-manufacturing plants, however, has not stimulated operation at more than 50 per cent capacity. Beer, Sondheimer & Company, of Frankfort, which was formerly foremost in the German metal business, has resolved to retire from the metal trade because of the continued depression. The company is not a member of Copper Exporters, of Brussels, as are the Metallgesellschaft, Aaron Hirsh, and Mansfeld, the other leading factors in German copper affairs.

. . . . Importation of unmanufactured aluminum into Italy has been prohibited by Mussolini because of the construction of new aluminum plants in that country. The prohibition will affect Aluminum Company of America more than any other producer.

Cut Bolivian Tin Output Again

La Paz, Bolivia, Nov. 1—Further curtailment in production of tin by Bolivian mines is being undertaken, as a result of continued low prices. For the first ten months, estimates place the ouput at about 25 per cent less than the 1929 rate of about 4,000 long tons monthly. Fabulosa Mines Consolidated has closed its Milluni concentrator, but continues to operate its plant at the Union property at full capacity. Both mills have a capacity of about 100 tons of ore daily. Rumors state that Patiño Mines, largest of the producers, is contemplating putting its properties on a one-shift basis, instead of the present five-day week with three shifts. Another report states that, because of lack of cheap power, the new Huanuni dredge will be forced to close until tin prices improve. The power company that had originally agreed to furnish the power for the operation has itself suspended work because of the lack of demand for its current, and other potential sources of power for the dredge are too costly with present low prices for the metal.

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BRIEF NOTES

Arizona Commercial. A stockholders' meeting has been called for Nov. 20, at Portland, Me., to consider the directors' recommendation that the company's property at Globe, Ariz., be sold to Old Dominion for $20,000. Production has been declining as ore reserves approach exhaustion, and the management has already announced that a shutdown by the first of next year is inevitable, particularly with current low copper prices. The property adjoins Old Dominion, which treats the ore in its mill.

Bullion Chief Mining. An underground milling plant, capacity 65 tons daily, has been constructed by the company 1,000 ft. from the portal of the main tunnel at its Maxfield property, in Big Cottonwood Canyon, Utah. Mill heads are said to average 10 per cent lead and 17 oz. of silver to the ton. The company is developing its mine with the hope of being able to build a larger concentrator in the spring. Connection of No. 1 raise with the No. 1 level has almost been completed.

Consolidated Mining & Smelting. Because of unfavorable base-metal markets, Consolidated has curtailed development work at several properties in Ontario. Crews have been withdrawn from the Beaver Mountain property, at Dean Lake, and the Anderson option, near Kashabowie. In British Columbia, the company is reducing the number of men employed at the Big Missouri mine, in the Portland Canal district. Mill construction is progressing favorably.

El Oro Mining & Milling. The company has acquired eighteen claims in the Boboquivari Mountains, 75 miles southwest of Tucson, Ariz., from Allison Mining. Roads to the property are now being graded and preparations are being made to build a twenty-stamp cyanide mill. F. C. Hulbert is president of the company and C. S. Schader, mining engineer and geologist, advised purchase of the property.

Eureka Standard. Sinking of the main shaft from the 1,300 to the 1,500 level of this silver-gold property in the Tintic district, Utah, is progressing at the rate of 100 ft. monthly, according to J. W. Wade, manager of the company, which is controlled by Tintic Standard. An auxiliary hoist has been installed at the 1,100 level to hoist waste from the sinking operations. Two 200-g.p.m. Worthington piston pumps have been installed on the 800 and 1,300 levels. At present water flow is only 15 g.p.m. A new Mancha storage-battery locomotive has also been installed.

North Butte Mining. A stringer of solid bornite and copper glance has been cut east of the Continental fault on the 2,200 level of this property at Butte, Mont. This is the first ore ever opened east of the fault. If it develops into a sizable orebody, it may greatly expand the extent of operations at Butte.

Premier Gold. The deal with Planet Mines for control of its property at Nicola, B. C., has been abandoned, but the company has taken an option on the Lakeview group, on Mount Ollie, 60 miles up the North Thompson River from Kamloops, where rich gold ore has recently been discovered in association with arsenopyrite. A camp is being built, preparatory to thorough exploration.

Tom Reed Gold. A crosscut is being driven on the 1,100 level of the property at Oatman, Ariz., to cut the Aztec orebody. At the end of October, it was in 170 ft. Production of ore from the new orebody on the 950 and 1,100 levels is enabling a monthly gold output of about $100,000. The daily mill tonnage from the mine is 100 tons, in addition to a small tonnage from leasers and the adjoining United American mine.

United Verde Extension. At the property at Jerome, Ariz., the diamond-drilling program adopted a year ago has been concluded. No ore was cut by this exploration. Other development work in the known ore area has been progressing with a slight increase in the known tonnage of ore in sight (estimated at 625,000 tons of 7.5 per cent copper ore on Dec. 31), but nothing else of importance has transpired at the mine.

Walker Mining. Nearly all development work now being done at the mine in Plumas County, Calif., is below the 710 or main tunnel level. A winze has been sunk in the Piute orebody to the 1,000 level to connect with the South and Central shafts at that depth. A Jeffrey multi-blade fan, with a capacity of 30,000 cu.ft. a minute, has been installed in the mine to insure ventilation. Production continues at the capacity of 1,600 tons of ore daily.

Western Exploration. This company has acquired the Ophir Hill property, at Ophir, Utah, formerly owned by the late Senator W. A. Clark. The necessary equipment for development work has been installed, and the west drift on the main tunnel level is being extended into virgin ground. A crosscut is being driven on the upper levels to explore the Top and Topmost ore horizons. Carbonate lead ore is being mined in the west drift. E. S. Bowman is superintendent.

Active Demand for Copper on 9½c. Basis—Zinc Higher on Cut in Production

New York, Nov. 6, 1930.—In the three weeks ended yesterday, the market for non-ferrous metals attracted wide interest because of the action of copper and zinc. In the case of the former the price fell to the basis of 9½c., delivered Connecticut, with a similar reduction in the export quotation, which, coming at a time when conferences of leading copper producers aimed at world-wide restriction of output were being held in New York, induced some good buying on the part of both domestic and foreign consumers. Zinc came to life in the third week of the period because it was understood that the low prices had forced an important general cut in domestic production. Tin was extremely unsettled, but the net change in prices was insignificant. Lead prices were unchanged, with the market steady. Quicksilver and antimony prices were down on slow business.

Excellent Call For Copper

As soon as the price of copper declined to 9½c., delivered Connecticut, the demand picked up appreciably. Domestic sales during the last two weeks amounted to slightly more than 60,000 tons, most of the tonnage sold being for delivery over the first quarter of next year. Inquiry for April forward business was very much in evidence, but sellers did not care to offer copper so far ahead under present conditions.

The export quotation was reduced to 9.80c., c.i.f. European ports, Oct. 25. This announcement was followed by an urgent demand for copper from abroad, especially from Germany and France. Copper Exporters, Inc., sold more than 56,000 long tons of copper in the last fortnight. European buyers took all the copper that they could get under the allotment plan of the association. Buyers on the other side were greatly disturbed over a contraction in offerings, but it was known here that European sellers had held back supplies before any action was taken here. The situation, briefly, is that all sellers are unwilling to push business at current prices as long as there is any hope for an understanding for world-wide curtailment in production of copper.

Conferences were held almost daily by highest executives of foreign and domestic copper producers at work on the curtailment problem. That copper production will be reduced appears certain; the question to be decided is whether the move will be voluntary or involuntary.

Zinc Price Up

After holding at 3.95@4c., St. Louis, for about two weeks, the zinc market suddenly came to life. Sales for the week ended Nov. 5 were the largest in volume in six weeks. The quotation climbed steadily; the weighted average price for business done on Nov. 5 was 4.35c. per pound. Before the close on that day leading sellers were holding out for 4.40c. The sudden activity has come about because it is understood that the low prices have forced an important cut in production, which should end the monthly mounting of stocks of both Prime Western and High-Grade. Producers have become unwilling sellers. Stocks of zinc in the United States on Nov. 1 were estimated by the American Zinc Institute at 141,232 tons, against 132,947 tons a month previous. A year ago the stocks totaled 59,592 tons.

Lead Unchanged

Steady prices in London more than offset quiet trading conditions here, and the market for lead held at 5.10c., New York, the contract quotation of the American Smelting & Refining Company, and 4.95c., St. Louis. World production of lead in September totaled 148,506 tons, against 155,364 tons in August, and 151,356 tons in July. A year ago production was around 160,000 tons.

Tin Unsettled

Conflicting reports on production developments in the Straits Settlements unsettled the market, and prices fluctuated sharply at times, though the net change for the period was slight. The world's visible supply of tin decreased to the extent of 474 tons during October, but, as a market factor, this was nullified by news to the effect that the carry-over in the East was larger than expected. Domestic consumers were good buyers, placing orders well into 1931.

Silver Steady

The price of silver changed but little in the last three weeks. The tone of the market was steady, owing to moderate offerings by leading operators and a fair demand from both India and China.

Other Metals

Quotations cover wholesale lots, f.o.b. New York, unless otherwise specified. London prices are according to latest mail advices.

ALUMINUM—Per lb., delivered, unchanged, at 23.30c. for 99 and 98 per cent grades.

ANTIMONY—Per lb., duty paid, Chinese spot, 7⅛c.; futures, 7c. Cookson's "C" grade, spot, 12⅛c. "C.M.C." grade, 99.9 per cent, spot, 10¾c.

Average Metal Prices for October, 1930

COPPER:	
Electrolytic, refinery	9.597
London Standard Spot	43.030
London Electrolytic Spot	45.772
LEAD:	
New York	5.151
St. Louis	4.999
London Spot	15.747
London Forward	15.674
SILVER:	
New York	35.846
London	16.563
Sterling Exchange	485.719
ZINC:	
St. Louis	4.059
London Spot	14.446
London Forward	14.935
TIN:	
Straits	26.802
London Standard Spot	117.451
QUICKSILVER	110.596
ANTIMONY	7.288
PLATINUM:	
Refined	36.000
ALUMINUM 99 Per Cent Plus	23.300

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BISMUTH—Per lb., $1. London, 4s.

CADMIUM—Per lb., 70c.

IRIDIUM — Per oz., $190@$200 for 98@99 per cent sponge and powder. London, £37@£39.

NICKEL—Per lb., ingot and electrolytic (99.9 per cent), 35c. for single lots of spot metal. Contracts less. Shot, 36c.

PALLADIUM — Per oz., $22@$23. London £3 15s. to £4.

PLATINUM—Per oz., official price of leading interest $36. Market firm. Cash transactions between dealers and refiners at several dollars less. London quotes £7 per oz., with outside lots available at concessions.

QUICKSILVER—Per 76-lb. flask, $106 @$109. Demand moderate, even at the reduced prices.

RHODIUM—Per oz., $45@$50. Nominal.

RUTHENIUM—Per oz., $36@$40.

Chromium, Cobalt, Magnesium, Manganese, Molybdenum, Osmium, Radium, Selenium, Silicon, Tantalum, Tellurium, Thallium, and Tungsten are unchanged from prices given in the Oct. 23 issue.

Metallic Ores

Prices in tons of 2,000 lb., or in "units" of 20 lb., unless otherwise stated.

CHROME ORE—Per long ton, c.i.f. Atlantic ports, Indian ores, 46 to 48 per cent Cr_2O_3, $19.50. Other prices in Oct. 23 issue.

IRON ORE—Per unit, foreign ores alongside docks Atlantic ports, cargo lots, North African and Swedish, low phosphorus, 10½c.; Spanish and North African basic, 50 to 60 per cent, 9½@ 10c. Other prices in Oct. 23 issue.

MANGANESE ORE—Per long ton unit of Mn, c.i.f. North Atlantic ports, cargo

Daily Prices of Metals

Oct. Nov.	Electrolytic Copper	Straits Tin	Lead		Zinc
	Refinery	New York	New York	St. Louis	St. Louis
16	9.775	26.10	5.10	4.95	3.95@4.00
17	9.775	26.50	5.10	4.95	3.95@4.00
18	9.775	26.50	5.10	4.95	3.95@4.00
20	9.525@9.775	26.75	5.10	4.95	3.95@4.00
21	9.275@9.775	27.125	5.10	4.95	3.95
22	9.275@9.775	27.10	5.10	4.95	3.95
Av'ge	9.671	26.679	5.100	4.950	3.967
23	9.275	26.80	5.10	4.95	3.95@4.00
24	9.275	27.10	5.10	4.95	3.95@4.00
25	9.275	27.50	5.10	4.95	3.95@4.00
27	9.275	27.10	5.10	4.95	3.95@4.00
28	9.275	27.15	5.10	4.95	3.95@4.00
29	9.275	27.00	5.10	4.95	3.95@4.00
Av'ge	9.275	27.108	5.100	4.950	3.975
30	9.275	26.90	5.10	4.95	4.00
31	9.275	26.75	5.10	4.95	4.05@4.10
1	9.275	26.50	5.10	4.95	4.25
3	9.275	25.75	5.10	4.95	4.25@4.30
4	Holiday	Holiday	Holiday	Holiday	Holiday
5	9.275	25.60	5.10	4.95	4.30@4.40
Av'ge	9.275	26.300	5.100	4.950	4.190

Average prices for calendar week ended October 18, 1930, are: Copper, 9.775c.; Straits Tin, 25.850c.; New York Lead, 5.100c.; St. Louis Lead, 4.950c.; Zinc, 3.980c.; Silver, 36.050c.

Average prices for calendar week ended October 25, 1930, are: Copper, 9.421c.; Straits Tin, 27.063c.; New York Lead, 5.100c.; St. Louis Lead, 4.950c.; Zinc, 3.967c.; and Silver, 35.729c.

Average prices for calendar week ended November 1, 1930, are: Copper, 9.275c.; Straits Tin, 26.900c.; New York Lead, 5.100c.; St. Louis Lead, 4.950c.; Zinc, 4.042c.; and Silver, 35.854c.

London

Oct. Nov.	Copper Standard		Electrolytic	Tin		Lead		Zinc	
	Spot	3 M		Spot	3M	Spot	3M	Spot	3M
16	42 7/8	42 15/16	46 1/2	113	114 1/2	16	15 15/16	14 3/4	15 1/4
17	42 13/16	42 7/8	46 1/2	115 3/8	116 3/4	15 3/4	15 7/8	15	15 1/2
20	42 3/4	42 13/16	46 1/2	114 1/2	116 1/4	15 11/16	15 7/8	15	15 1/4
21	43 7/16	43 5/16	46 1/2	118 3/8	120	15 7/8	15 11/16	14 7/8	15 3/8
22	42 11/16	42 5/8	45 3/4	119	120 1/2	15 7/8	15 11/16	14 7/16	14 13/16
23	41 3/4	41 13/16	45	115 3/4	117 1/4	15 1/2	15 7/16	14 1/8	14 1/2
24	41 3/8	41 7/16	44	116 1/2	118 1/4	15 3/8	15 5/16	14 1/4	14 11/16
27	41 1/8	41 3/8	44 1/4	117 1/2	119	15 9/16	15 1/2	14 1/4	14 11/16
28	41 1/16	41 7/8	44 1/4	118 7/8	120 1/2	15 3/8	15 5/16	14 3/16	14 5/8
29	43	42 1/16	44 1/4	118 3/8	119 7/8	15 1/2	15 1/2	14 9/16	14 7/8
30	43 1/8	43 3/8	44 1/4	118 3/4	120 1/4	15 3/8	15 5/8	14 3/8	15 1/8
31	44	44	45 1/4	118 1/8	119 1/2	15 1/16	15 11/16	14 3/4	15 1/8
3	43 11/16	43 1/2	45 1/4	113 7/8	115 1/4	15 3/8	15 3/4	14 11/16	15 1/4
4	43 3/8	43 3/8	45 1/4	111 1/4	112 3/8	15 1/16	15 1/16	15 7/16	15 5/8
5	42 7/8	42 3/4	45 1/4	111 1/2	112 7/8	15 1/16	15 1/16	14 7/8	15 3/8

Prices for lead and zinc are the official prices for the morning session of the London Metal Exchange; prices for copper and tin are the official closing buyers' prices. All are in pounds sterling per long ton (2,240 lb.).

Silver, Gold, and Sterling Exchange

Oct.	Sterling Exchange "Checks"	Silver		Gold London	Oct. Nov.	Sterling Exchange "Checks	Silver		Gold London
		New York	London				New York	London	
16	4.85 13/16	36 1/8	16 11/16	84s 11 1/2d	27	4.85 5/8	35 3/4	16 7/16	84s 11 3/4d
17	4.85 13/16	36 1/8	16 5/8	84s 11 1/2d	28	4.85 5/8	35 3/4	16 1/2	85s 00 1/4d
18	4.85 13/16	35 7/8	16 5/8	.....	29	4.85 11/16	35 3/4	16 1/2	85s
20	4.85 1/2	35 7/8	16 9/16	84s 11 1/2d	30	4.85 3/8	35 7/8	16 1/2	85s
21	4.86 1/16	35 7/8	16 5/8	85s 0 1/4d	31	4.85 9/16	35 7/8	16 9/16	85s
22	4.85 13/16	35 3/4	16 1/2	85s 0 1/4d	1	4.85 3/8	36 1/4	16 9/16	.....
23	4.85 13/16	35 1/2	16 3/8	85s 0 1/4d	3	4.85 11/16	36 1/2	16 3/4	85s 0 1/4d
24	4.85 1/2	35 3/4	16 1/2	84s 11 3/4d	4	Holiday	Holiday	16 11/16	85s 0 1/4d
25	4.85 1/2	35 5/8	16 7/16	.....	5	4.85 7/16	36 1/8	16 11/16	85s 0 1/2d

Average for week ended October 22: Silver, 35.938c; Sterling Exchange, $4.85865.
Average for week ended October 29: Silver, 35.688c.; Sterling Exchange, $4.85667.
Average for week ended November 5: Silver, 36.100c.; Sterling Exchange, $4.85638.

New York quotations are as reported by Handy & Harman and are in cents per troy ounce of silver, 999 fine. London silver quotations are in pence per troy ounce of bar silver, basis of 925 fine. Sterling quotations represent the demand market in the forenoon. Cables command one-sixteenth cent premium.

lots, exclusive of duty of 1c. per lb. of Mn contained, Indian, 48 to 50 per cent, 27@28c.; South African, 52 to 54 per cent, 27@28c.

Chemical grades, per ton, in carload lots, powdered, coarse, or fine, $60, f.o.b. mines, or Atlantic ports.

TUNGSTEN ORE—Per unit of WO_3, New York: Chinese wolframite, duty paid, $12.25@$12.50. Bolivian scheelite, $13; domestic scheelite, $13@$14; both nominal.

Antimony, Beryllium, Molybdenum, Tantalum, Tin, Titanium, Vanadium, and Zircon ores are unchanged from prices given in the Oct. 23 issue.

Non-Metallic Minerals

Quotations for non-metallic minerals are unchanged from those published in the issue of Oct. 23.

Alloys

Alloy prices are unchanged from those given in the Oct. 23 issue.

Metallic Compounds

Prices given for metallic compounds in the Oct. 23 issue are unchanged.

Refractories

Refractories are unchanged from the prices given in the Oct. 23 issue.

Rolled Metals

COPPER—Per lb., sheets, hot-rolled, 19¼c.; wire, f.o.b. mill, 11¼c.

LEAD SHEETS—Per lb., full rolled, 8c; clipped, 8¼c.

MONEL METAL—Per lb., sheets, full finished, 42c.; rods, hot-rolled, 35c.

MUNTZ METAL—Per lb., rods, 15⅞c.; plates, 18⅝c.

NICKEL—Per lb., sheets, full finished, 52c.; rods, hot-rolled, 45c.

NICKEL SILVER—Per lb., sheets, 10 per cent, 24@24½c.; 18 per cent, 27¼@27¾c. Wire and rods, 10 per cent, 27½c., 15 per cent, 31¼c.; 18 per cent, 34¾c.

PHOSPHOR BRONZE—Per lb., sheets and rods, 5 per cent tin, 30½c.; wire, 5 per cent, 31c.; 10 per cent, 36½c.

ZINC SHEETS—Per lb., 9½c., f.o.b. works; ribbon, 9c.; 7 per cent discount on orders for 18 tons or more.

Iron, Steel, and Coke

IRON—Per gross ton, Valley furnaces: Bessemer, $18; basic, $17; No. 2 foundry, $17.

STEEL—Per gross ton, base prices. Pittsburgh, billets and slabs, $31; plates and structural shapes per 100 lb., $1.60; soft steel bars, $1.60@$1.65.

COKE—Per ton, Connellsville furnace, $2.60. Connellsville foundry, $3.50@$4.85. Byproduct coke, Ohio and Kentucky (Connellsville basis), $5.50; Buffalo, $8@$8.50; Detroit; $8.50; Birmingham, $5.